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Continuum Mechanics and Discrete Systems 9

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ABSTRACTS

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Topic: 3
Title: *Experimental Approach to Continuum Dislocation Fields in Polycrystalline Materials*
Summary

EXPERIMENTAL APPROACH TO CONTINUUM DISLOCATION FIELDS IN POLYCRYSTALLINE MATERIALS

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Described in this paper is the application of orientation imaging microscopy (OIM) and calibrated serial sectioning to determine the local curvature field in deformed bicrystalline and polycrystalline samples. Based upon automated electron microdiffraction technique, OIM obtains data on the 2-D field of local lattice orientation. When coupled with serial sectioning and polishing, 3-D fields can be interrogated. Challenges with the experimental methods are described, including the problem of achieving registry between data sets obtained on adjacent section planes, methods for optimizing the experimental resolution of lattice misorientation, and the complications associated with the geometry of the microstructure (grain boundaries).

.Connections between the data and the fundamental equation of continuum dislocation theory are examined. From such an approach estimates of the local geometrically necessary dislocation tensor have been obtained. When evaluated by orthogonal and non-orthogonal representations, estimates of the total geometrically-necessary dislocation density have been obtained. Examples of results from bicrystalline and polycrystalline samples are shown. Interpretations of the results in terms of net Burger~s vector content and grain boundary trap/sink behavior are presented.

Acknowledgement: This work was supported by the MRSEC Program of the National Science Foundation under Award Number DMR-9632556. The bicrystal samples were provided by W. King of Lawrence Livermore National Laboratories

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Topic: 4
Title: *Nonlinear Wave Modulation in a Two Layered Elastic Medium*
Summary

NONLINEAR WAVE MODULATION IN A TWO LAYERED ELASTIC MEDIUM

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In this work the propagation of small but finite amplitude shear horizontal waves in a two layered elastic plate of uniform thickness is considered. It is assumed that the constituents materials are generalised neo-Hookean materials and stresses and displacements are continuous at the interface and the boundaries are free of tractions. The problem is investigated by employing the method of multiple scales, by assuming that the amplitude of waves is finite but small.

Between the linear shear velocities of the layers the following inequalities are valid $c_1<c_2$. Then, for the existence of an SH wave, the phase velocity c of the wave must satisfy either $c_1<c<c_2$ or $c_1<c_2<c$.

In both of these cases, it is shown that the nonlinear modulation of SH waves is governed by the nonlinear Schrödinger (NLS) equation. It is well known that the behaviour of solutions of the NLS equation depend on the sign of the product of its coefficients. By taking into account the properties of the solutions of NLS equations, the possibilities of soliton solutions and the modulational instability of plane waves for various nonlinear material properties of the layers are investigated.

Also for $c_1<c<c_2$ the formation of Love waves is observed.

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Topic: 6
Title: *Multiscale Effects in Friction*
Summary

MULTISCALE EFFECTS IN FRICTION

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In most mechanical systems, many different mechanisms contribute to friction between sliding surfaces. These include elastic and plastic deformation of asperities, particles and other third bodies in the interface, as well as photoluminescence and chemical reactions. While some of the contributions to friction can be modeled at the continuum scale, always, however, there is sliding at the molecular scale between

opposing surfaces or between one of the surfaces and the third bodies. This "microfriction" that has been the missing element in continuum-scale models is usually accounted for using an empirical "binomial law," for there is not a satisfactory analytical model for it available. Furthermore, friction is also strongly influenced by the response of the dynamic system within which it exists. In this presentation, after a brief description of the scale effects in friction, a model of friction within the context of a dynamic system will be shown. The friction model is based on deformation of asperities and their adhesion as represented by the binomial law. Influence of each on the response of the dynamic system will be discussed. Also, a brief overview will be given of the attempts to model microfriction by means of simple forms of vibration of atoms.

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Topic: 6

Title: *On the Determination of the Theoretical Strength Limit in Compression of Unidirectional Composite Materials*

Summary

ON THE DETERMINATION OF THE THEORETICAL STRENGTH LIMIT IN COMPRESSION OF UNIDIRECTIONAL COMPOSITE MATERIALS

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At present the theoretical strength limit in compression of unidirectional composite materials have been investigated in framework of the continual approach. According to this approach, the considered material with piecewise-constant properties is modelled by a structurally homogeneous orthotropic material with normalized mechanical properties and it the compressive forces $\sigma_{11}^0 = p_1$, $\sigma_{22}^0 = p_2$, $\sigma_{33}^0 = p_3$, $\sigma_{ij}^0 = 0$, $(i \neq j)$ are applied on this material at infinity (σ_{ij}^0 are precritical stresses). After above procedure the equations of the three-dimensional linearized theory of stability are written for the foregoing continuous medium and the type changing of these equations are investigated. In this case the values of p_i corresponding to the loss of ellipticity of above equations are taken as theoretical strength limit of the considered material.

In the present paper in the framework of the piecewise-homogeneous body model with the use of exact geometrically nonlinear equations, the approach for the investigations of the above-described theoretical strength limit of the foregoing materials is proposed. In this case the investigations are carried out on the composite material consisted of the alternating layers of two isotropic homogeneous material and

the plane deformation are studied. It is proved that the results obtained in the framework of the continual approach coincide with the corresponding results obtained in the framework of the proposed approach.

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Topic:
Title: *Nonlinear Wave Modulation in a Prestressed Viscoelastic Thin Tube Filled With an Inviscid Fluid*

NONLINEAR WAVE MODULATION IN A PRESTRESSED VISCOELASTIC THIN TUBE FILLED WITH AN INVISCID FLUID

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In the present work, the propagation of weakly nonlinear waves in a prestressed thin viscoelastic tube filled with an incompressible inviscid fluid is studied. Considering that the arteries are initially subjected to a large static transmural pressure P_0 and an axial stretch λ_z and, in the course of blood flow, a finite time dependent displacement is added to this initial field, the governing nonlinear equation of motion in the radial direction is obtained. Using the reductive perturbation technique, the propagation of weakly nonlinear waves in the long-wave approximation and the amplitude modulation of weakly nonlinear waves are examined.In the first place, the general evolution equation is obtained in the long-wave approximation, and then it is shown that by a proper scaling of various quantities, this master equation reduces to the well-known nonlinear evolution equations such as Burgers', KdV and KdVB. Secondly, we studied the amplitude modulation of weakly nonlinear waves and obtained the dissipative nonlinear Schrödinger equation. Finally, the envelop solitary wave solution is obtained in the absence of dissipative term.

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Topic: 6

Title: *The Local and Nonlocal Non-smooth Pseudoparabolic Systems, Their Riemann Functions and Applications*

Summary

THE LOCAL AND NONLOCAL NON-SMOOTH PSEUDOPARABOLIC SYSTEMS, THEIR RIEMANN FUNCTIONS AND APPLICATIONS

Seyidali Akhiev *and* Esin Inan
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The investigation of some filtration problems and the propagation of non-steady shearing waves in some media can be reduced to the boundary value problems of pseudoparabolic differential equations. The general form of such equations may be written as follows

$$D_t^n D_x^m u + \sum_{i=0}^{n}\sum_{j=0}^{m} A_{i,j}(t,x) D_t^i D_x^j u = Z(t,x), \quad (t,x) \in G = (t_0,t_1)\times(x_0,x_1) \qquad (1)$$

Here $D_z = \partial/\partial z$ denotes the differentiation operator in the sense of Sobolev, n and m are positive integers.

In the present study, the coefficient functions, $A_{i,j}(t,x)$ are assumed non-smooth, in general and $A_{i,j}(t,x) \in L_p(G)$ for $1 \le p \le \infty$ where $L_p(G)$ is the space of functions on G which are p-integrable. In the first step of the investigation , a new type of partial integration formula is given for the equations with nonlocal and non-smooth coefficients. Then the concept of fundamental solution is introduced by using this new formulation. The resulting fundamental solution may be considered as the particular solution of the two dimensional integral equation and regarded as the generalized form of the classical Riemann function.

Equation (1) is the generalized equation of filtration problem for m=1 and n=2. For m=n=2 , it represents the wave equation in a dissipative medium. In the present work, the obtained general results are applied to the second problem and the corresponding wave equation is investigated.

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Topic: 6

Title: *Weakly Nonlinear Waves in a Prestressed Thin Elastic Tube Containing a Viscous Fluid*

Summary

WEAKLY NONLINEAR WAVES IN A PRESTRESSED THIN ELASTIC TUBE CONTAINING A VISCOUS FLUID

Nalan ANTAR *and* Hilmi DEMİRAY
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In this work, we studied the propagation of weakly nonlinear waves in a prestressed thin elastic tube filled with an incompressible viscous fluid. In order to include the

geometrical and structural dispersion into analysis, the wall's inertial and axial force effects are taken into account in determining the inner pressure-inner cross sectional area relation. Using the reductive perturbation technique, the propagation of weakly nonlinear waves in the long-wave approximation is shown to be governed by Korteweg-de Vries-Burgers (KdVB) equation. Due to dependence of coefficients of the governing equation on the initial deformation, material and viscosity parameters, the profile of travelling wave solution to KdVB changes with these parameters. The profile of travelling wave solution of the evolution equation is evaluated numerically depicted in some figures. The formation of shock profile with initial deformation and viscosity of for circumferential stretch ratio and the viscosity of the fluid and the results are the fluid is throughly discussed.

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LAGRANGE FORMALISM AND DISSIPATION IN MATERIAL CONTINUA

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Frequently one meets the opinion that dissipation does not fit into Lagrange formalism (LF). By LF I mean the formalism which is associated with Hamilton's Variational Principle in its original sense, i.e. which from an *action integral* results in the fundamental field equations of the system as well as in its complete dynamics, defined via Noether's Theorem from universal invariance requirements for the Lagrangian.

Along the line of the *Inverse Problem* of variational calculus there is a well established procedure which takes account of dissipation due to friction by means of variational principles, the kernels of which, e.g., depend explicitly on time. So, only part of the above mentioned statement is fullfilled: The field equations are equivalent to the set of Euler-Lagrange equations. The dynamics of the system associated with Noether's theorem, however, is still missing. The dissipated energy, e.g., is disappearing in an undefined nowhere. Formally speaking, one is dealing with an open system. Its relevant physical complement is still missing for thermodynamical exchange.

In my opinion this lack is due to a too poor description of dissipation in traditional attempts towards a LF of dissipation. Friction or viscosity coefficients, e.g., are too rough representatives of a very involved microscopical physics. On the phenomenological level one should take into account the microphysics to a certain extent. So, in order to involve dissipation into LF on the phenomenological level I propose to take account of this physics to some extent by means of *transfer variables*. The method will at first be demonstrated for the case of point mechanics. Then the

generalization for *dissipative processes of deforming material continua* will be outlined. This will be most important for a *continuum theory of plastic deformation based on the dynamics of dislocations*: Due to various microscopical processes dislocation dynamics is extremely dissipative. As a main feature the transfer variables give rise to an *irreversible energy transfer from mechanical degrees of freedom to thermal degrees of freedom*. This transfer is due to an appropriate coupling of the mechanical and thermal variables by means of the transfer variables. As an essential structure of the theory the thermal degrees of freedom have to be taken into account by means of the *complex thermion field*, which is a fundamental concept of thermodynamics of irreversible processes as described within the unifying concept of LF. The physical interpretation of the transfer variables depends on the particular system.

Examples will be given for Coulomb- and Stokes-friction of a moving body and perspectrively for the creeping motion of dislocations of a plastically deforming material.

Keywords: Dissipation, friction, dislocation dynamics, plasticity, Lagrange formalism, thermodynamics of irreversible processes, transfer variables

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Topic: 3
Title: *Biological Polymers : Dynamics and Solitons*
Summary

BIOLOGICAL POLYMERS: DYNAMICS AND SOLITONS

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The structure of basic biological polymers as the DNA and proteins is discussed. Based on these structures, idealized models for some modes are indicated. Specifically, equations are derived to describe proton magration in hydrogen bonded chains, the denaturation of the DNA, the rotor motion of base pairs in a DNA double helix and the dynamics of a helical coil treated as a continuum. The mathematical modelling is in terms of non-lineer difference equations which are later turned into non-lineer partial differential equation in the continuum description. Both soliton solutions and general non-lineer dynamics are discussed. The influence of external fields is also discussed for the proton migration model and the presence of an external field is shown to lead to the destruction of solitons.

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Topic: 6
Title: *Dynamical Field Theory of Dislocations within Lagrange Formalism*
-- Cosserat fluid and complex dislocation fields --
Summary

DYNAMICAL FIELD THEORY OF DISLOCATIONS WITHIN LAGRANGE FORMALISM " -- THE COSSERAT FLUID AND COMPLEX DISLOCATION FIELDS --

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Plastic deformation of crystals is due to the motion, generation and interaction of dislocations. %Dislocation dynamics plays the role of a link In early works we presented the main guidelines to establish a phenomenological continuum theory of single crystal elasto--plasticity based on the microdynamics of dislocations. The model demonstrates how a continuously dislocated crystal lattice may be viewed as generalized Cosserat fluid, i.e., a continuum in which each particle is endowed with a triad of vectors, called Cosserat directors. The latter are intended to describe the microstructure of the fluid whereas their torsion is associated with the dislocation density tensor. The approach starts by dividing the dislocation network into various classes of dislocations of equal type, i.e., roughly speaking of different slip systems. Each class is associated with a complex dislocation field giving rise to the definition of the partial density of dislocations and their average drift velocity. By means of complex dislocation fields a dynamical field theory of crystal dislocations can be formulated within the framework of Lagrange Formalism.

The presented paper is intended as an advance of this approach in order to account for some mechanical as well as thermal aspects of dislocation dynamics. In order to obtain a more refined description of the dislocation pattern we distinguish whitin one class of dislocations between two dislocation species, the mobile and the immobile (forest) dislocations. The mobility of dislocation is a necessary condition of dislocation production. The model involves the mechanism of creations and annihilation of dislocations (Frank--Read mechanism). %due to external stress fields. Furthermore dislocation dynamic is extremely dissipative: During plastic flow the applied mechanical work is almost completely dissipated giving rise to heat production. The thermodynamics of dislocations has to be established as a non--equilibrium dynamics. Dissipation occuring during plastic flow is associated with an irreversible energy transfer from mechanical to thermal degrees of freedom, i.e., between the dislocation fields and the fields of thermal excitation (thermion field). In this way the Lagrange formalism based on the concept of complex field variables presents itself as an appropriate tool for an unified description of mechanical and thermal effects of plastic deformation.

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Topic:
Title: *An Investigation of Pulsatile Flow In A Slowly Tapered Tube*

AN INVESTIGATION OF PULSATILE FLOW IN A SLOWLY TAPERED TUBE

Hilmi DEMİRAY *and* İlkay BAKIRTAŞ
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In this work, pulsatile flow in a slowly tapered tube is studied. The fluid is assumed to be incompressible and Newtonian whereas the tube is considered to be incompressible and elastic. Considering the physiological conditions under which the arteries function, the stress distribution is obtained. Superimposing a small, dynamical displacement field upon this static field, the governing incremental equations for both fluid and tube are obtained. Assuming that the tapering angle is small, the field quantities are expended into the power series of this small angle parameter. Substituting this expansion into the field equations and the boundary conditions, a set of differential equations and boundary conditions are obtained. Then a solution is sought which is harmonic in time, to the field equations and an analytical result is obtained for the zeroth and first order equations.

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Topic: 4
Title: *Rheology of Suspensions*
Summary

RHEOLOGY OF SUSPENSIONS

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A formula is proposed for the effective shear viscosity for a suspension. This formula is a modification of a formula first given by Saito to which a function of the volume fraction is added containing the effects due to correlations and hydrodynamic

interactions between the suspended particles. Earlier theoretical results for spheres are used to obtain values for the lowest virial coefficient in the expansion of this function in the volume fraction. A comparison is made with experimental data both for hard spheres and for water in oil microemulsions. In the last case the temperature dependent aggregation of the inverse swollen micels is found to explain the behaviour of the virial coefficients and binding enthalpies of the aggregates can be evaluated.

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Topic: 2
Title: *Elasticity and Fracture in the Polyacrylamide Gels*
Summary

ELASTICITY AND FRACTURE IN THE POLYACRYLAMIDE GELS

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Polyacrylamide gels present very particular elastic properties in that the Young modulus does not always increase with the amount of the cross-link agent but has a maximum. This effect is related to the inhomogeneous structure of the gels as indicated by neutron scattering, In the present investigation, we shall report recent results of the fracture strength of these gels as it influenced by the amount of polymer and the cross link agent. The fracture strength is compared to linear and non linear elasticity. A tentative interpretation, in connection with the heterogeneties appearing in the gels, is also exposed.

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Topic: 3
Title: *Communications and Cooperation in Coplex Bacterial Colonies*
Summary

COMMUNICATION AND COOPERATION IN COMPLEX BACTERIAL COLONIES

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In nature, bacterial colonies must often cope with hostile environmental conditions. To do so the bacteria have developed sophisticated cooperative behavior and intricate communication capabilities, such as: direct cell-cell physical interactions via extra-

membrane polymers, collective production of extracellular "wetting" fluid for movement on hard surfaces, long range chemical signaling such as quorum sensing and chemotactic (bias of movement according to gradient of chemical agent) signaling, collective activation and deactivation of genes and even exchange of genetic material. Utilizing these capabilities, the bacterial colonies develop complex spatio-temporal patterns in response to adverse growth conditions. We study a wealthof beautiful patterns formed during colonial development of various bacterial strains and for different environmental conditions. Invoking ideas from pattern formation in non-living systems and using generic modeling we are able to reveal novel bacterial strategies which account for the salient features of the evolved patterns. Using the models, we demonstrate how bacterial communication leads to colonial self-organization that can only be achieved via cooperative behavior of the cells. It can be viewed as the action of a singular feedback between the micro-level (the individual cells) and the macro-level (the colony) in the determination of the emerging patterns.

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Topic: 2

Title: *On the Effective Conductivity of Composites with Ellipsoidal Inclusions and Superconducting Interfaces*

Summary

ON THE EFFECTIVE CONDUCTIVITY OF COMPOSITES WITH ELLIPSOIDAL INCLUSIONS AND SUPERCONDUCTING INTERFACES

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The effective conductivity of composite media at which the phase interfaces exhibit a thermal contact resistance has been studied since the seventies [Garrett and Roserberg (1974), Benveniste and Miloh (1986), Hasselman and Johnson (1987), and others]. At the phase interfaces of such media the normal component of the heat flux is continuous whereas the temperature field suffers a discontinuity. There exists a counterpart of non-ideal interfaces at which the temperature field is continuous but the normal component of the heat flux undergoes a Jump which is proportional to the surface Laplacian of the temperature field at these locations, Similar behaviour in the mathematically analogous context of electrical transport phenomena is also existent. The study of such composites systems is only very recent [Torquato and Rintoul (1995), Lipton (1997), Cheng and Torquato (1997)]. It can be shown that an interface exhibiting a discontinuity in the normal component of the heat flux is a limiting representation of a thin superconducting interphase.

In the present paper we consider a composite medium containing ellipsoidal inclusions with superconducting interfaces. The ellipsoidal shape allows the study of a wide range of particle morphologies from thin disc via spherical particles to long thin fibers. In the first part of the paper a fundamental framework is formulated for the definition and determination of the effective conductivity tensor of these system. The analysis is direct and avoids the use of energy concepts. In the main part of the paper, the dilute approximation which neglects interaction is derived. As is well known, this model is based on the solution of an auxiliary, problem involving a solitary particle in an infinite medium. An exact solution of this problem for the present case, hitherto unknown, is presented by making use of ellipsoidal harmonics. Due to the superconducting interface the intensity inside the inclusion is not uniform but can be obtained in terms of infinite series. The dilute approximation is not only of fundamental importance of its own but also forms a connerstone of other approximate mean field theories for non-dilute concentrations. Such approximations are derived in the concluding section of the paper. When applied to the case of spherical particles at random distributions they give results in agreement with those obtained recently by Cheng and Torquato (1997) by other means.

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Topic: 1
Title: *Equilibrium States in Volume Scattering of Acoustic Waves in a Channel*
Summary

EQUILIBRIUM STATES IN VOLUME SCATTERING OF ACOUSTIC WAVES IN A CHANNEL

Mark J. Beran
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Alan M. Whitman
Villanova University

When acoustic waves are scattered by random sound-speed fluctuations in a two-dimensional channel the energy is continually transferred between the propagating modes. In the multiple-scattering region the energy flux assumes an asymptotic form in which there is equal energy flux propagating in each mode. Here we shall make use of this well known result to show how to obtain an asymptotic form for a pulse of acoustic energy propagating in the channel. In the multiple scattering region the speed of the acoustic waves in the pulse continually changes as the energy is transferred between the modes. The process is basically a diffusion process around the mean speed of propagation. We shall first show, using physical arguments, that the diffusion coefficient is proportional to the square root of the propagation distance times the mean free path of scattering. The theory governing the acoustic propagation in the

channel is formulated in terms of modal coherence equations and we shall next give a brief review of the definitions of the coherence functions and a discussion of how the equations governing the propagation of the modal coherence functions are derived. We shall then show that for very large propagation distances there is equipartition of the energy flux among the propagating modes. Finally, we shall show how the pulse shape and the relevant parameters may be obtained by solving the basic modal coherence equations at large propagation distances.

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Topic: 2-GL
Title: *Thermodynamics of Chaos*
Summary

THERMODYNAMICS OF CHAOS

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Three plot lines will be interwoven in this presentation. The first one goes back to the well-known Boltzmann program "to derive thermodynamics from mechanics." Boltzmann found answers foralmost all the principal questions except the question of the mechanical sense of entropy. This was done by G. W. Gibbs and P. Hertz. The Gibbs-Hertz formula will be discussed in detail.

The second plot line takes its origin in Smoluchovsky's explanation of the critical opalescence phenomenon. This phenomenon is observed if one slowly heats a vessel with transparent liquid. Near the boiling point, the liquid suddenly becomes nontransparent. The explanation by Smoluchovsky was as follows: near the point of the liquid-vapor phase transition, fluctuations of the density grow, light is scattered, and the fluid becomes nontransparent. To construct a theory of this phenomenon,
A. Einstein suggested a relation between fluctuations and thermodynamical functions, which is the cornerstone of the modern theory of thermodynamical fluctuations. At equilibrium, thermodynamical parameters fluctuate and have a certain probability density function. In the case of fluids, the Einstein formula establishes the connection between the probability density function of the density, $f(\density)$, and the entropy of the fluid, $\S$, which is also a function of density $\density $, $$ f(\density) = c e^{\S(\density)}$$ where c is a normalizing constant. This formula is striking. It links quantities coming from different ``scientific galaxies." On the right-hand side of the Einstein relation we see entropy, which is representative of a completely deterministic theory, in which there is no place for any randomness. The left-hand side is characteristic of a random process.

Einstein referred this relation to the well-known Boltzmann formula

$$S = k \ln W$$

where W is the number of microstates compatible with the given macrostate. At first glance, the Einstein formula looks like the inversion of the Boltzmann relation since W, up to a factor, is probability. In fact, the Einstein formulation introduces a new physical meaning: it did not follow from Boltzmann's studies that the connection between entropy and probability can be used in the Einstein sense.

The derivation of the Einstein relation ``from mechanics" is another topic of the lecture. It turns out that the Einstein relation has an asymptotical nature and is true if the number of degrees of freedom, n, tends to infinity. We will derive an exact relation, which is valid for all n and for large deviations from equilibrium.

The third plot line is the contemporary development of the first two and is only slightly sketched. It starts from the fact that thermodynamics is nothing else but an "average description" of a system based on separation of slow ``macromotion" and fast"micromotion". Therefore, ``thermodynamical questions" can be posed, practically, for any system, performing either ordered or chaotic motion: there are always some parameters of the system which can be changed slowly. A system can be as simple as a nonlinear oscillator and as complex as turbulent flow. We will discuss one class of systems -- systems with small dissipation. We will show that slightly dissipative systems possess the major feature of classical equilibrium thermodynamics: potentiality of constitutive equations. The corresponding "thermodynamical" potential (it is called here the dynamical potential) has the sense of a Lagrange function averaged over the attractor.

In contrast to the thermodynamics of attractors, the statistical mechanics of attractors is at an embryonic stage. Examples show that low-dimensional attractors hardly admit a simple statistical description. The hope is that, in physically interesting problems, high dimensionality may create comprehensible statistical behavior. In particular, it is not impossible that statistical behavior of slightly dissipative systems, under certain circumstances, can be approximated by the corresponding ergodic Hamiltonian mechanics. From this perspective, some aspects of the statistical mechanics of an ideal incompressible fluid will also be considered.

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Topic: 2

Title: *Efficent method for Calculating Elastic Moduli of two-Component composites with Complicated but Periodic Microstructures*

Summary

EFFICIENT METHOD FOR CALCULATING ELASTIC MODULI OF TWO-COMPONENT COMPOSITES WITH COMPLICATED BUT PERIODIC MICROSTRUCTURES

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The local displacement field u(r) in such a system satisfies an integro-differential equation. That equation is transformed into an infinite set of linear algebraic equations for the Fourier expansion coefficients of u(r). Instead of solving those equations, their matrix is used to generate an expansion of the bulk effective stiffness moduli Ce as power series in the contrast between the two components. That series is then transformed into a continued fraction which provides a sequence of increasingly better approximants for Ce. In some cases this is ach ieved by having, at each stage, an upper and lower bound on Ce. These bounds get progressively tighter, and always converge to the correct value of Ce. At every finite order, these bounds provide an exact range of values where Ce must lie.

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Topic: 2
Title: *Statistical Mechanics of Vortex Matter*
Summary

STATISTICAL MECHANICS OF VORTEX MATTER

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Traditionally, the normal to superconducting phase transition of bulk material has been regarded as being well described within mean field theory. This view has changed with the discovery of the copper oxide superconductors with a high transition temperature of order 100 Kelvin: with a Ginzburg number of the order of 10^{-2} - 10^{-1}, fluctuations turn out to be about 6 - 8 orders of magnitude stronger than in conventional low T_c material. One of the most striking consequences of the strong fluctuations is the realization of a vortex lattice melting transition and the appearance of a new vortex liquid phase, occupying a large fraction of the *H-T* phase diagram. Recent experiments in anisotropic $YBa_2Cu_3O_7$ and layered $Bi_2Sr_2Ca_1Cu_2O_8$ superconductors have demonstrated the first-order nature of the vortex lattice melting transition. Theoretically, this phase transition can be described using various techniques: i) A simple Lindemann analysis provides the shape of the melting line. ii) Mapping the vortex system to 2D "charged" bosons, the latter can be investigated via a path integral Monte Carlo simulation, providing the Lindemann number, the latent heat of transition, the volume contraction upon melting, and the nature of the resulting liquid phase. iii) Scaling arguments predict the temperature and field dependence of the jumps in entropy and volume at the phase transition. The theoretical results agree well with all experiments obtained to date on the strongly fluctuating high-T_c superconductors.

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Topic: 1-GL
Title: *The Flux-Line Lattice in Superconductors*
Summary

THE FLUX-LINE LATTICE IN SUPERCONDUCTORS

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Type-II supercoductors like Niobium and its alloys, and the new High-Temperature Oxide-Superconductors, are penetrated by magnetic flux lines, or vortices of supercurrent, each carrying one quantum of magnetic flux $\Phi_0 = h/2e$. These Abrikosov vortices arrange to a more or less perfect triangular flux-line lattice. With increasing applied magnetic field the density of vortices increases until the material becomes normal conducting at the upper critical field B_{c2}. The flux-line lattice exhibits interesting non-local elasticity and may be plastically deformed, amorphous, or even melted.

Under the action of an applied electric current the vortices can move and dissipate energy. This undesired vortex drift is suppressed by introducing material inhomogeneities which pin the vortices. The calculation of the average pinning force density, or of the maximum loss-free current density J_c, is a difficult statistical problem in which the non-local elasticity of the vortex lattice plays a crucial role.

In the new High-Temperature Superconductors (HTSCs) the vortices may depin by thermal activation, causing non-zero resistivity even at current densities far below J_c. Thermal depinning is favored by the high transition temperature of HTSCs, by their small pinning energies, and by the large anisotropy of these layered materials, which reduces the line tension of the vortex lines and thus facilitates the depinning of short vortex segments or even of individual vortex disks in the copper-oxide layers. At higher temperatures these disks of which each vortex line consists, may even ``evaporate'' into a gas of vortex disks. The resulting current--voltage law of HTSCs is highly non-linear.

In typical measurements of the magnetic response, the superconductor is a thin platelet or film exposed to a **perpendicular** magnetic field. Up to quite recently, appropriate theories for the evaluation of such experiments were not available but one resorted to theories which were derived for long slabs or cylinders in **parallel** field. For other specimen shapes one used corrections by a demagnetization factor, but this works only for homogeneous specimens with elliptical shape and linear response.

Recent exact analytical results extend the **static** Bean model to thin disks and strips of constant thickness in a perpendicular magnetic field. Analytical and numerical methods yield also the **dynamics** of the magnetic flux in thin strips, disks, squares, and rectangles treated as non-linear conductors. These results were now extended to specimens of finite thickness.

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Topic: 8
Title: *A Kinetic Model for Granular Materials*
Summary

A KINETIC MODEL FOR GRANULAR MATERIALS

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Already in 1903 Reynolds, in his paper on the Submechanics of the Universe, proposed a very general continuum theory of granular materials. He suggested the addition to the classical equation of balance of another equation which rules the evolution of a symmetric tensor H. Also the theory of hypoelasticity, Grad's theory of 13 moments, extended thermodynamics, Jenkins' theory of fast flow of granular materials, all come to a similar proposal; at the same time, a very simple constitutivelaw is suggested for Cauchy's stress tensor $T = \rho H$ (where ρ is the density). Thus, in the gross motion, momentum is influenced by convection terms; for this class of materials the name 'kinetic continua' seems appropriate. Some general properties are reviewed; consequences on the equations of thermodynamics are explored.

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Topic: 7
Title: *Nonlinear Scattering of Waves by Cracks*
Summary

NONLINEAR SCATTERING OF WAVES BY CRACKS

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Abstract Wave propagation in an elastic medium in the presence of distributed cracks is of interest in areas of engineering, rock mechanics and geophysics. The theoretical description of the scattering process, accompanied by experimental observations of velocity variation and attenuation of ultrasonic waves, provides a means of detection and characterisation of damage in the material, in the context of nondestructive evaluation. The theoretical model can be also useful for estimating the extent of fracturing in the region of a borehole, in the extraction of oil, or for analysing the seismic behaviour of rock layers. In the present work, cracks are supposed to be randomly distributed and, using a configurational averaging procedure, the problem is formulated in terms of mean values of displacement, strain and stress fields. A constitutive relation containing an additional field of internal variables is employed. The internal variables describe the mean opening ofthe cracks and they are determined through an evolution law relating theambient field to the single crack response. The single crack response is governed by a boundary integral equation and, since dynamic contact between crack faces can occur, the response turns out to be nonlinear. This is reflected in a nonlinear dynamic behaviour of the overall medium. A unilateral constraint is introduced, corresponding to opening of the crack during tension and closure during compression. For general loading conditions, contact can occur on different portions of the crack surfaces at different times, giving rise to a mixed boundary value problem with moving boundaries. Hence,the problem is discretized both in space and time domain, and a computational scheme is proposed to analyse the evolution of the response.

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Topic: 4-Defect Dynamics
Title: *Material Symmetries and Singularities in Solids*
Summary

MATERIAL SYMMETRIES AND SINGULARITIES IN SOLIDS

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In this work we examine the relations between the symmetry group of a crystalline or solid body and the line singularities in the deformation (or microstructural) field which this material can support. A method is developed which, in some relevant cases (dislocations and crystalline defects), allows to associate to a singularity a

suitable current, with singular support the defect submanifold, which measures the obstruction to the extension of the local deformation (or microstructure) to a globally defined field. This procedure yields the basis of a formulation of weak field equations for a defective material, and allows to clarify the structure of the compatibility relations for virtually any class of material symmetries.

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Topic: 2
Title: *Statistcal Physics of Fracture Breakdown in Disordered Solids*
Summary

STATISTCAL PHYSICS OF FRACTURE BREAKDOWN IN DISORDERED SOLIDS

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The statistical properties of mechanical fracture of disordered solids, or electrical failure (dielectric breakdown or fuse) of random electrical networks, which were originally studied and analysed empirically by the engineers, have recently been understood by employing the statistical physics of percolation (theory and models). The application of statistical physics allowed the possibilities of several predictions, checked in experiments and laboratory simulations. We intend to discuss these developments.

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Topic: 2
Title: *Unstable Variational Problems in Solid Mechanics.*
Summary

UNSTABLE VARIATIONAL PROBLEMS IN SOLID MECHANICS.

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A number of exciting problems in solid mechanics are formulated as unstable variational problems. Among them: structural optimization, bounds on composite

properties, phase transitions in solids, inverse problems of determination of material's structure and of nondestructive testing. Solutions of these problems are characterized by fine scale spatial inhomogenuities that come from non-quasiconvexity of Lagrangians and that are realized as media with microstructures. Dealing with these problems, one has to determine "the best" structure of a material. We discuss methods for analysis of unstable problems, especially the technique of necessary conditions, and the translation method for sufficient condition. These methods establish averaged constituence relations in an optimal structure, and provide conditions for the fields in each material inside the mixture. The applications deal with optimal micro-geometries of multicomponent mixtures. Also, we discuss dynamics of a transition in natural unstable systems that leads to a micro-inhomogeneous equilibrium. This dynamics is characterized by oscillations that transform energy to a high-frequency mode, which leads to energy dissipation. The modelling and homogenization of a discrete chain of masses and unstable springs is discussed.

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Topic: 2
Title: *Generalized Wave Equations Containing Production/Dissipation Mechanism and the N otion of Dissipative Solitons*
Summary

GENERALIZED WAVE EQUATIONS CONTAINING PRODUCTION/DISSIPATION MECHANISM AND THE NOTION OF DISSIPATIVE SOLITONS

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Generalized wave equations containing energy production/dissipation mechanism arise in the mechanics of continua when the wave propagation in rods, thin-liquid films, etc, is modeled. In many cases localized solutions (coherent structures) exist whose shapes bring an exact balance between the energy production, dissipation, nonlinearity, and dispersion. This is a generalization of the classical Boussinesq balance for conservative systems involving merely the nonlinearity and dispersion. We investigate the interaction and evolution of these coherent structures by means of difference schemes faithfully representing the balances. We find that although during collisions the shapes of the coherent structures may not be always preserved they can still qualify for what is called ``quasi-particles" and their interaction resembles the classical solitonic collisions. As a featuring example we consider a generalized wave equation in a moving frame is approximated by the Kuramoto-Sivashinsky nonlinear evolution equation. The important observation is that after two K-S coherent

structures separate well enough after a collision they eventually resemble their initial shape and propagate steadily.

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Topic: 2
Title: *Statistical Aspects and Size Effect in Toughness of Concrete*
Summary

STATISTICAL ASPECTS AND SIZE EFFECT IN TOUGHNESS OF CONCRETE

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A systematic experimental investigation of size effect in toughness of concrete and statistical modeling of brittle fracture based on the concept of an ensemble of virtual crack trajectories are presented in this paper. The experiments were conducted on six groups of specimens with the same shape and the sizes ranging from 105x105x12.5mm to 1680x1680x200mm with the scaling factor of 2 between the groups. Six different maximum aggregate sizes were selected to maintain the same maximum aggregate to specimen size ratio. Thus the six groups of completely similar specimens, i.e., specimens with the same macro- and microscopically dimensionless parameters, were among the tested ones. The specimens were repeatedly loaded until the crack inception and then unloaded. The crack trajectories and increments was monitor via a video-recording system. Finite Elements Method was applied to evaluate the elastic energy release rate (ERR) for each experimentally observed crack trajectory. The critical values GIC of ERR at each crack inception for each crack trajectory were recorded as a function of crack length. It display a typical R-curve behavior, i.e., GIC increases with the crack length. Comparison of GIC vs. dimensionless crack length, i.e., R-curves within the groups with the given scaling factor but different sizes shows noticeably higher R-curve for larger specimens than that for the smaller ones. It suggests the presence in brittle fracture of some hidden dimension of length that is not accounted for by the aggregate and the specimen sizes. It may be related to the local tortuosity of crack path. The modeling of the observed R-curve behavior, size effect and scatter of GIC values are based on the concept of an ensemble of virtual crack trajectories and crack propagation through a microheterogeneous brittle solid. Experimental examination of the model is discussed.

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Topic: 5
Title: *Anisotropic Models in Multiplicative Finite Elastoplasticity*
Summary

ANISOTROPIC MODELS IN MULTIPLICATIVE FINITE ELASTOPLASTICITY

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The paper deals with some old and new models obtained in the framework of axiomatic approach to elastoplastic behaviour of materials with crystalline structure given by Cleja-Tigoiu, Soos [1990], founded on Mandel's type multiplicative decomposition of the deformation gradient, $F = F^e F^p$. The behaviour of elastoplastic materials is described with respect to the relaxed (intermediate) configuration by an elastic type constitutive equation and evolution equations, which take into account the dissipative nature of the plastic flow as well as the texture development and ciorresponding anisotropy. Based on thermodynamic arguments some thermodynamical dualities can be established (in Maugin [1992]) between different stress measure and their appropriate rates of plastic deformations, which effectively produce a dissipation. these conjugate variables are considered as a basis for the formulation of thermodynamically admissible evolution equations in the finite (isothermic) elastoplasticity. Some Σ- models for anisotropic body are proposed when the yield condition is dependent on Σ, Mandel's stress measure (or on the quasi-static Eshelby stress tensor, given in Epstein, Maugin [1990]), which is the conjugate variable to $L^p = \dot{F}^p (F^p)^{-1}$. The extension of the dissipation postulates (given in Marigo [1989], Lucchessi, Podio-Guidugli [1990]), allow us to prove that the appropriate flow rule is defined up to a term that belongs to the kernel of $(\partial_G \hat{\Sigma}(G))^T$, via the elastic constitutive equation $\Sigma = \hat{\Sigma}(G), G = (F^e)^T F^e$ Our result is similar to Lubliner's one [1990]. Moreover the conditions for the hypoelasticity in Hill's sens derived by Cleja-Tigoiu [1994] are fulfilled. The combined isotropic-kinematic hardening Σ- models, which involve the existence and the development of transverse isotropy are formulated. Two alternative constitutive equations for plastic spin are emphasized, corresponding to moderatly large and to small elastic strains, respectively. In order to analyse the influence of different constitutive descriptions on the predicted material response, the rate form of the virtual velocities, in an updated Langrageian description is derived, by using the proved hypoelasticity. The obtained results can be used to better understand the role of the plastic spin in describing large elastoplastic deformations.

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Topic: 1-GL
Title: *Order-Disorder and Phase Separation: Modeling Grain Sintering*
Summary

ORDER-DISORDER AND PHASE SEPARATION: MODELING GRAIN SINTERING

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An Allen-Cahn/Cahn-Hilliard system is derived by taking a quasi-continuum limit in discrete molecular dynamics to obtain a diffuse interface model for simultaneous order-disorder and phase separation. By developing asymptotics in the proximity to a deep quench limit, and assuming spatial scales which model Krzanowski instabilities, limiting equations of motion are derived which couple motion by mean curvature of APBs with motion by minus the surface Laplacian of two IPBs on the same time scale. This framework should be suitable for describing sintering of small grains and thermal grain boundary grooving in polycrystalline films. (Part of this work reflects collaboration with J.W. Cahn.)

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Topic: 1
Title: *Continuum Modelling of Flows with Nucleation and Condensation*
Summary

CONTINUUM MODELING OF FLOWS WITH NUNLEATIOON AND CONDENSATION

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Flows with homogeneous condensation in expansion cloud chambers, supersonic nozzles and corner expansions are considered. The flow of the mixture of condensable vapor and carrier gas is modelled as a homogeneous two-phase flow. Condensation

takes place as a result of homogeneous nucleation followed by droplet growth. The nucleation equation can then be taken as a functional relation of the independent thermodynamic coordinates whereas the droplet growth law may assume different forms (eg. free molecular growth, continuum growth in transition regime) depending on the Knudsen number. The condensation rate equation, constructed from these laws and coupled. to the equations of flow and state, is then solved asymptotically in the limit of a large nucleation period followed by a small droplet growth time exhibiting the condensation zones,. Asymptotic expressions are shown to yield satisfactory agreement with experiments and numerical simulations.

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Topic: 6
Title: *Towards a united Approach to the Fracture, Yielding, and Damage*
Summary

TOWARD A UNITED APPROACH TO FRACTURE, YIELLING, AND DAMAGE

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Several one-dimensional models reproducing failure, strain localisation, or damage , have been proposed recently. Their many common features suggest the possibility of a unified treatment, and good perspectives in this direction seem to emerge from the energetic approach.

This approach has obtained considerable success in applications to materials with nonconvex strain energy, such as-shape-memory alloys and rubber-like materials. It is also at the basis of Griffit's theory of fracture and of Barenblatt's cohesive crack model. The latter is based on the interplay of a bulk energy, defined on the volume of the body, and of a cohesive energy, defined on the crack surface; it has been employed successfully to identify brittle and ductile failure modes, and to estimate the influence of the size of a body on rupture.

It has been recently found that, by varying the shape of the cohesive energy, the same model is able to reproduce phenomena outside the domain of fracture. Indeed, simple

one-dimensional schemes involving a bulk and a cohesive energy have provided a rather detailed representation of yielding, of elastic unloading, and of the oscillations observed in tensile tests made at a very slow strain rate. Conjectures based on recent progresses in continuum theories of damage point towards incorporation of damage into the same unifying scheme.

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Topic: 3
Title: *Mathematical Modelling of Soft Biological Tissues and Solitary Waves in Arteries*
Summary

MATHEMATICAL MODELING OF SOFT BIOLOGICAL TISSUES AND SOLITARY WAVES IN ARTERIES

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The propagation of pressure pulses in fluid-filled compliant tubes is a problem of interest since the time of Thomas Young, who first obtained the pulse speed in arteries by treating it as a linear elastic material. The published literature on this subject is so rich that it is almost impossible to cite all these works here. However, almost in all these works, the arterial wall material is treated as a linear elastic (or viscoelastic) material and the effect of initial deformation is neglected. In addition, the majority of works in this area is concerned with harmonic wave propagation and dispersion relation by employing the linearized field equations. In reality, the arterial wall material undergoes into large deformation when performing its function. Moreover, considering that for a healthy human being the systolic pressure is around 120 mmHg, diastolic pressure is 80 mmHg and the axial stretch is 1.6, in the course of blood flow, it is seen that the arterial wall material is subjected to a large initial static deformation.

In the present work, considering the physiological conditions under which the areteries function, we proposed a quasi-linear viscoelastic model for the arterial wall material. Then, treating the arterial wall as a cylindrical long thin tube filled with a fluid and employing the constitutive relation we proposed for soft biological tissues, the nonlinear equation of motion in the radial direction is obtained. Utilizing the exact equations of fluid and the reductive perturbation method, we studied the propagation of weakly nonlinear waves for the long-wave limit. Depending on the order of nonlinearity and of the viscoelastic effects, it is shown that the governing evolution equation can be described as Burgers' equation, Korteweg-de Vries equation (KdV) or the combination of these equations, i.e., KdVB equation, namely,

$$\frac{\partial U}{\partial \tau}+\chi U\frac{\partial U}{\partial \xi}-\nu\frac{\partial^2 U}{\partial \xi^2}+\sigma\frac{\partial^3 U}{\partial \xi^3}=0 \qquad (1)$$

where U is the radial displacement of order ε, τ and ξ are respectively the time and space coordinate parameters, χ, ν, and σ are some constants which depend on the initial static deformation, material and geometrical characteristics.

KdVB equation characterizes the case where the dispersive and dissipative effects are comperable and they are balanced by the nonlinearity. This equation has the travelling wave solution of the form

$$U=\frac{3v^2}{25\chi 5}(sech^2\vartheta+2tanh\vartheta+2) \quad ;\vartheta=\frac{3v^3}{125\sigma^2}\tau-\frac{v}{10\sigma}\xi. \tag{2}$$

Since the coefficients appearing in (1) depend on the initial deformation, material and geometrical characteristics, the wave profile changes with these parameters.

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Topic: 2
Title: *Energetics of Fine Domain Structures*
Summary

ENERGETICS OF FINE DOMAIN STRUCTURES

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In the last two decades, numerous new mathematical tools have emerged in the literature on Calculus of Variations for the analysis of minimization problems involving non-convex free energies. These advances, sometimes stimulated by the attempt to answer questions formulated by physicists and engineers, have shed some new light on the behavior of a variety of physical systems exhibiting domain structures, and on their response to external actions (forces, electromagnetic fields, etc.). Examples range from ferroelastic solids, and, in particular, shape memory alloys, to ferromagnetic materials, to solids with strong electro- or magneto-elastic coupling, to liquid crystalline polymers. The author will review such examples, and contrast theoretical predictions with experimental observations.

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Topic: 3-6
Title: *Elements of a Theory of Material Growth*
Summary

ELEMENTS OF A THEORY OF MATERIAL GROWTH

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In this attempt at developing a theory of diffusive material growth (mass creation or resorption such as in living organisms), the latter is viewed as a local rearrangement of material inhomogeneities described by means of first-and second-order uniformity >, the first of these having possibly a determinant larger than one. Accordingly, in agreement with the general theory of material uniformity and inhomogeneity (Noll, Wang) and its most recent developments (Epstein-Maugin, 1990 on), an essential role is played by the balance of canonical (material) momentum-ie., the balance of momentum on the material manifold, in which the flux associated to canonical momentum is the so-called Eshelby material stress tensor. Growth is shown to develop a force source of quasi-inhomogeneity of its own in this equation. The corresponding irreversible thermodynamics is expanded. If the constitutive theory of basically elastic materials is only first-order in gradients, the diffusion of mass growth cannot be accommodated, and volumetric growth then is essentially governed by the inhomogeneity velocity "gradient" (first-order transplant theory) while the driving force of irreversible growth is shown to be Eshelby stress or, more precisely, the "Mandel" stress (already introduced in some invariant theories of finite-strain elastoplasticity) -although the possible influence of "elastic" strain and its time rate is not ruled out. Restrictions imposed upon the growth evolution equation by (I) uniformity of the material, (ii) so-called "G-covariance", (iii) frame indifference, and (iv) material symmetry, are carefully implemented, yielding a rather simple and reasonable evolution law. In the second-order theory which does allow for growth diffusion, a second-order inhomogeneity tensor -related to the difference between two connections-need be introduced; but it is possible to envisage a special theory where the time evolution of the second-order transplant is slaved to that of the first-order transplant, avoiding thus insuperable complications. The geometrical background of the theory is developed in both cases, although not in an abstract way, within the finite-deformation framework. The second-order theory is based on the notion of so-called G-structures of differential geometry.

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Topic: 4
Title: *An Asymptotic Theory of Thin Micropolar Plates*

Summary

AN ASYMPTOTIC THEORY OF THIN MICROPOLAR PLATES

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Various theories have been proposed in recent years to incorporate the internal, discrete, structure of matter into the classical elasticity model. These theories take different names depending on which aspect of continuum has been chosen as a starting point. The theory of micropolar elasticity is concerned with an elastic medium whose constituents, the so-called material points, are allowed to rotate independently without stretch. The fundamental equations of a micropolar elastic medium then contain coupled microrotations and displacement fields [1]. A first attempt to construct a plate theory based on the linear theory of micropolar elasticity was made by Eringen [2]. Eringen's approach to the derivation of a micropolar plate theory involves *a priori* assumptions regarding the variation of the unknowns across the thickness of the plate.

In this study the asymptotic expansion technique is used to obtain the two dimensional dynamic equations of thin micropolar plates from the three-dimensional equations of micropolar elasticity theory. To this end, all the field variables are scaled via an appropriate thickness parameter such that it reflects the expected behaviour of the plate. Then, the three-dimensional solution is expanded in powers of the thickness parameter and the hierarchies of the field equations are obtained. It is shown that the zeroth order approximation includes the standard assumptions on the specific forms of the field variables, which are assumed *a priori* in the literature. Moreover, Eringen's micropolar plate equations are obtained as the leading term of the formal asymptotic expansion. In the absence of polar effects, the plate equations coincide with those of the classical plate theory.

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(In *Fracture* **II** ed. H.Liebowitz). Academic Press, New York (1968).

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Topic: 4
Title: *Multi-Scale Expansion of the Coupled Modified Kadomtsev-Petviashvili* Equation
Summary

MULTI-SCALE EXPANSION OF THE COUPLED MODIFIED KADOMTSEV-PETVIASHVILI EQUATIONS

Saadet Erbay
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In a previous study [1], it has been shown that the behavior of nonlinear waves propagating in a micropolar elastic solid is governed by the two coupled modified Kadomtsev-Petviashvili equations in the long-wave approximation. In recent years, various authors have studied the wave modulation for a number of nonlinear evolution equationsin 1+1 and 2+1 dimensions. It is well-known that the multi-scale expansion methods allow one to obtain new evolution equations which differ from the original ones. In the present study, using the multi-scale expansion method, various nonlinear partial differential equations, depending on the scale parameters, in 2+1 dimensions are obtained from the two coupled modified Kadomtsev-Petviashvili equations. These evolution equations are in agreement with those obtained previously in the literature.

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Topic: 1
Title: *Non-commutative geometry and irreversibility*
Summary

NON-COMMUTATIVE GEOMETRY AND IRREVERSIBILITY

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In ordinary quantum mechanics, the non-commutativity of the position and momentum operators, on which the Heisenberg uncertainty principle is based, has led to speculations about the intrinsically discrete nature of space and time. A lattice generated by discrete translations is transformed, under an exponential change of variables, to a periodic lattice on the logarithmic scale. A kinetics built upon q-calculus, the calculus of discrete dilatations, is shown to describe diffusion on this hierarchical lattice. The only observable on this ultrametric space is the ``quasi-position" whose eigenvalues correspond to the volume of

phase space energetically available to be explored by the system at any given time. Motion along the hierarchical lattice of quasi-positions is irreversible, since the probability distribution expands monotonically to include each quasi -position as it is explored.

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Topic: 2

Title: *High Order Continuum Model for Incompressible Viscous Fluid Flow and Application to Numerical Modeling of Thermo-Vibrational Convection.*

Summary

HIGH ORDER CONTINUUM MODEL FOR INCOMPRESSIBLE VISCOUS FLUID FLOW AND APPLICATION TO NUMERICAL MODELING OF THERMO-VIBRATIONAL CONVECTION

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The generalized hydrodynamic equations (GHE) by Alexeev[1] obtained from a generalized Boltzmann kinetic equation, constitute the basis of the model. This model is investigated for the case of incompressible viscous fluid flow.

Governing equations contain a time-scale parameter τ we find to be related to the Kolmogorov scale of turbulence for the fluctuations which arise through the GHE. The value of τ is to be determined for particular problem.

We solve GHE equations numerically for the case of the lid-driven cavity problem and compare our 2D and 3D results with experimental data by Koseff and Street [2], which aimed to provide a 2D and 3D benchmarks for numerical codes.

New model allows the use of the simplest first order finite element interpolation for both velocity and pressure, which makes solution procedure simple and effective. We solved the problem by the finite element CFD code FEMINA [3,4]. It was used also to

solve the Navier-Stokes (NS) equation as well for the same problem. We used those results and ones obtained with a standard k-ε turbulence model for comparison.

The results of the model proposed are in good agreement with the experimental data for Re=3200 and 10^6 for 3D driven cavity flow are an improvement upon previous results obtained using the Navier-Stokes equation or k-ε turbulence models. The value of τ yields the spatial scale for statistical Kolmogorov fluctuation which agrees with the observed experimental one in [2].

New model was used for the numerical simulation of thermal convective flows. Experimental results by Putin et al [5] and finite-volume simulation by Bessonov [6] are used as a benchmarks in a Rayleigh number range from 1000 to 10^6.

We consider the application to particular problems of 3D thermal convection and thermo-vibrational convective flows in a cylindrical region, which is related to the investigation of a vibrational control of the Bridgman crystal growth technique[7]. Results are presented and discussed.

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Topic: 1
Title: *Sedimendation Phenomena and Structure in Suspensions*
Summary

SEDIMENTATION PHENOMENA AND STRUCTURE IN SUSPENSIONS

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The sedimentation of solid spherical particles in a viscous fluid is still not well understood and offers a number of fascinating problems connected to the structure of the suspension. We consider here non-Brownian particles for which the structure is governed by the hydrodynamic interactions between the particles. The Reynolds number of the flow around the particles is assumed to be small, so that Stokes equations apply. Various problems and some results will be presented here. The average velocity of sedimentation in a dilute and nearly monodisperse suspension admits several values depending on the way by which the limiting case of a monodisperse suspension is attained. For a dilute polydisperse suspension, there is an indeterminacy in the calculation of the average velocity of sedimentation in cases where permanent doublets may exist. For other cases of bidisperse suspensions in which no permanent doublets exist, recent experimental results suggest a curious history effect after the two types of particles have separated. The theoretical determination of the variance in the velocity of sedimentation is still a disputable problem. Experiments give a large variance of the order of the Stokes velocity, but theories and simulations generally give a much larger one, growing with the size of the container and eventually becoming theoretically infinite in an infinite suspension. The way by which the structure can limit the value of the variance is still under discussion.

Some theoretical and experimental results regarding the structure problem are presented here. Expressions are obtained for the pair probability and for the average velocity of sedimentation in an inhomogeneous polydisperse suspension. A promising experimental technique using pulsed field gradient Nuclear Magnetic Resonance (NMR) provides the structure factor. This technique, formally analogous to the light scattering used for colloidal suspensions, is applicable to non-Brownian suspensions. It is presently limited to dense suspensions but its applicability to less dense ones is under study.

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Topic: 2
Title: *Impact Damage Mechanisms In Laminated Composites.*
Summary

IMPACT DAMAGE MECHANISMS IN LAMINATED COMPOSITES.

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Continuos fiber laminated composites exhibit excellent properties, such as specific strength, fatigue, corrosion resistance, etc., which makes them desirable for a wide variety of structural applications in aerospace, marine, and oil industries. However, when using advanced composites, there is an overall lack of knowledge base on how to assess and characterize damage, progression of damage and subsequently design against it. In this work, we present the results of an experimental investigation whose aim is to elucidate the mechanisms governing the impact damage resistance of composite laminates to low velocity impacts which is a primary driver in the damage tolerance design of composites. Generic damage characteristics are reviewed and it is shown that they result from two different events during the impact process. First thelaminate experiences a local failure which resembles a Hertzian failure process. This occurs once the impact load reaches a critical threshold level and results in a collection of oriented matrix micro-cracks together with pairs of intra-ply radial cracks. Next, as the laminate continues to carry additional load, subsequent delamination occurs between the plies with the size of the delaminated area increasing with the increasing load. It is demonstrated that the value of the impact force is a critical parameter in defining the extent of damage in the laminate as oppose to the impact energy in itself. Also, methods are introduced to study the kinetics of the damage initiation and growth and results are presented for a range of different matrix resin systems.

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Topic: 5,6
Title: *Homogenization of Cosserat Materials :*
From Single Crystal to Polycrystal Generalized Plasticity
Summary

HOMOGENIZATION OF COSSERAT MATERIALS : FROM SINGLE CRYSTAL TO POLYCRYSTAL GENERALIZE PLASTICITY

Samuel Forest
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Several generalized crystal plasticity theories have been developed in the past few years to account for size effects in the mechanical behavicur of metal single crystals. In particular, a single crystal can be regarded as a Cosserat medium for which the lattice wryness tensor is related to the dislocation density tensor of the continuum theory of dislocations.

As a result, the polycrystal must be regarded as a heterogeneous Cosserat material. Classical honogenization theory enables one to derive the effective behaviour of the polycrystal starting from the constitutive properties of the grains. Some of these technics are extended to the case of heterogeneous Cosserat materials. The resulting

homogeneous equivalent medium is found to be a Cosserat medium also and the relations between the overall deformation, wryness, force and couple stresses and the local ones are given.

The usual homogenized polycrystal models, for instance according to the self-consistent scheme, can not account for size effects in polycrystals. In contrast the application of the previous homogenization methods leads to a polycrystal sensitive to grain size effects for instance. The representative volume element is taken as a three-dimensional agregate of elastoviscoplastic Cosserat grains. Adequate boundary conditions are applied to it. This is done using the finite element method. Parallel computing is required to deal with such large sets of degrees of freedom (displacement and microrotation) and internal variables (slip, curvature and torsion amount on each slip system). Finally, the effective Cosserat properties of polycrystalline copper are presented.

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Topic: 5
Title: *Diffusion in Non-Crystalline Solids, Particularly Metallic Glasses and Quasicrystals*
Summary

DIFFUSION IN NON-CRYSTALLINE SOLIDS, PARTICULARLY METALLIC GLASSES AND QUASICRYSTALS

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This research contribution aims at conveying our present understanding of the mechanisms of diffusion in non-crystalline solids, laying particular emphasis on metallic glasses and quasicrystals.

Based on a large body of experimental data and assisted by molecular-dynamics simulations, it is concluded that in metallic glasses different diffusion mechanisms operate in the as-produced, unstable, amorphous state and in the relaxed, metastable amorphous state achieved by moderate thermal annealing. In the unrelaxed glassy state, diffusion takes place via an indirect mechanism involving (quasi-)vacancies, quenched-in in supersaturation, as diffusion vehicles. The decay of this excess concentration of vacancies is reflected by a decrease of the diffusivities during isothermal diffusion annealing. In the relaxed amorphous state the diffusivities show Arrhenius-type temperature dependences, which indicate that the underlying diffusion mechanisms are thermally activated. Among the metallic glasses investigated, the

pre-exponential factors of the (mostly self-)diffusion coefficients and the corresponding diffusion enthalpies range from 10-7 m2s-1 and 1.5 eV for Fe diffusion in Fe91Zr9 to 10+7 m2s-1 and 3.2 eV for Zr diffusion in Zr76Fe24, respectively. This is interpreted in terms of direct collective diffusion mechanisms which gradually change from the jumping of single atoms into nearby vacant sites produced by thermal fluctuations (small diffusing atoms in loosely packed alloys) to thermally activated displacement chains comprising up to 10 atoms or more (big diffusing atoms in densely packed alloys).

Studies of the diffusion in quasicrystals have concentrated on icosahedral AlPdMn. The diffusing elements investigated so far apparently diffuse via vacancy-type mechanisms. In the case of Pd and Au, there is a change-over from a vacancy mechanism above 4500C to a phason-assisted collective diffusion mechanism below this temperature. Similarities to diffusion mechanisms in metallic glasses are elaborated.

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Topic: 2
Title: *Continuum Models of Plane Elastic Cellular Media*
Summary

CONTINUUM MODELS OF PLANE ELASTIC CELLULAR MEDIA

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Iwona Cielecka *and* Margaret Wozniak
University of Technology, L odz, Poland

The objective of the contribution is to formulate and apply a new continuum model to study linear elastodynamics for a plane cellular medium of an arbitrary periodic structure.

It is assumed that the length dimensions of a representative cell of the periodic structure are small compared to the minimum characteristic length dimension of the whole medium and that the mass distribution can be approximated by assigning a concentrated mass and an inertia moment to every nodal point of a cellular medium. Hence, the medium under consideration is represented by a certain plane periodic system of mutually interacting rigid joints. The direct approach to dynamics of periodic systems with a very large number of interacting rigid bodies leads to computational difficulties due to a large number of ordinary differential equations describing the problem under consideration. That is why different averaged continuum models of periodic discrete systems have been proposed in order to simplify the analysis of special problems.

The aim of the contribution is to formulate a refined continuum model of the medium under consideration, i.e. a nonasymptotic model which describes the representative periodicity cell size effect of on the global body behaviour. This model can be applied to the analysis of a linear elastic plane cellular media with an arbitrary complex lay-out of the representative cell.

The main feature of the model is its relatively simple analytical form given by the partial differential equations of the plane Cosserat continuum coupled with the system of ordinary differential equations involving second order time derivatives of certain extra unknowns called internal variables. The results are applied to the investigation of free vibrations and wave propagation problems.

The physical correctness of the model proposed is shown by comparing the obtained solutions and the exact ones.

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Topic: 2
Title *On the Derivation of the Beaver and Joseph Boundary Condition in the Mechanics of Porous Media*
Summary

ON THE DERIVATION OF THE BEAVER AND JOSEPH BOUNDARY CONDITION IN THE MECHANICS OF POROUS MEDIA.

Ahmed GHALEB
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The theory presented by I.A. Murdoch in dealing with the boundary conditions at the surface of a porous medium is used to derive Beaver and Joseph boundary condition. A discussion of the involved constant follows.

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Topic: 8
Title: *Remarks on Equations for Fast Granular Flows*
Summary

REMARKS ON EQUATIONS FOR FAST GRANULAR FLOWS

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In [1] a mathematical description of the fast flow of granular materials was developed within a continuum scheme which couches the system of evolution equations proposed in [2], where the Grad's method of moments was used for determining the form of balance laws including the collisional transfers and productions due to inelastic clashes of grains.

In that scheme peculiar constitutive choices can be done for the Cauchy's stress, the third-order stirring tensor and the contribution to the stir of internal dissipative collisions; choices which involve both gradients of velocity and of Reynolds' tensor and that permit to find significant explicit solutions for an ample subclass of flows (see [3]).

Here, we propose more general constitutive relations and analyze steady shearing motions. Then we perform an analysis of stability of stationary solutions and investigate the waves propagation in one-dimensional flow. Also, by allowing granular agitation perpendicular to the direction of flow, we find solutions which generalize the results in [3].

Finally, we calculate the Lie group of point transformations with respect to which the one-dimensional equations of granular materials remain invariant. By using this invariance we obtain some particular exact solutions. Alternatively, we use these symmetries in order to introduce some invertible transformations enabling us to map the governing equations into other equivalent forms (see [4]).

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Topic: 5. Dislocation and Plasticity
Title: *Mesomechanics of PSB Ladder Structure Formation*
Summary

MESOMECHANICS OF PSB LADDER STRUCTURE FORMATION

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The evolution of persistent slip bands (PSBs) and their ladder structure is treated consequence of the instability transition accompanied by the process of self-organization of dislocations stored in the deformed metal crystal. The proposed qualitative 2D~model is described by the equation of motion for glide dislocations and the equations of elasto-plastic continuum deformed by single slip. The analysis of linearized equations at the state of zero hardening, which simulates a disintegrating dislocation vein structure, predicts an appearance of shear bands of localized slip. The second order perturbation indicates that within the bands of localized slip a new dislocation structure of the ladder type may appear. The wave length of the dislocation structure formed in the bands represents the intrinsic length scale controlling the average width and density of PSBs. The thickness of the PSBs is estimated using minimization of the elastic strain energy of the internal stresses. The basic assumption is that the glide properties of dislocations in all active slip planes of the PSB lamellae of localized shear are the same. The evaluated ratio of the wave length of the dislocation structure in PSBs to the average width of PSBs is comparable to the measured values. The predicted proportionality of the density of PSBs to the applied plastic strain amplitude is in agreement with the observation.

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Topic: 4
Title: *Evolution of Snow-Firn Properties : a Thermomechanical Approach*

Summary

EVOLUTION OF SNOW-FIRN PROPERTIES : A THERMOMECHANICAL APPROACH

E.Guseva and V.Berdicevskij

The interest in experimental and theoretical study of the snow-cover thermodynamic properties is caused by the fact that its spatial and temporal variability plays an important role inatmospheric and ladge-scale climate processes. Snow cover accumulatedon the polar ice caps reveals pronounced temporal variability of all parameters (temperature, thickness, density, structure,strength) during a winter period. It results in the heat- and mass-transport processes,being highly sensitive to different external changes. To study the physical properties of snow in different meteorological conditions the mathematical model is offered in this paper. It is used for numerical estimations of the influence of the polar ice cap.

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Topic: 3-GL

Title: *Effect of Interfacial Bonding on the Mechanical Properties of Bone Tissue*

Summary

EFFECT OF INTERFACIAL BONDING ON THE MECHANICAL PROPERTIES OF BONE TISSUE

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Cortical bone tissue has been modeled as a short fiber reinforced composite material. It is composed of an organic matrix comprised mainly of Type I collagen reinforced by a mineral crystal similar to carbonated hydroxyapatite. Fiber geometry and bonding between the constituents of short fiber composite are the major determinants of its mechanical properties. In certain pathological conditions such as osteoporosis, the bonding between the organic and the mineral phase of bone tissue could be altered and the result is a mechanically inferior bone structure. The bonding of the bone mineral to the organic constituents is due to the affinity of the mineral and organic for each other (electrostatic, chemi-adsorption, etc.).

We have developed an *in vitro* ion treatment method to alter the mechanical properties of the bone using fluoride and phosphate ion solutions. Changes in the mechanical properties of the bone tissue such as elastic modulus, ultimate stress, and ultimate strain are dependent on the ionic strength and the duration of exposure to the treatment. The fluoride ions can be adsorbed to the bone mineral surface as well as

exchange with the hydroxyl ions and some of the carbonate ions. If the bone is exposed to a high ionic strength fluoride solution, ion exchange will occur and there will also be partial dissolution and reprecipitation of the bone mineral. In contrast, phosphate ions only adsorb onto the surface of the bone mineral. Treating bone with different amounts of fluoride and phosphate ions, one can alter the crystal structure as well as the interface between the mineral and organic phases. This experimental technique allows us to investigate how alterations in the mineral crystal and in the interfacial bonding effect the mechanical properties of bone tissue.

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Topic: 1
Title: *Nonpolynomial Expansion Near Fixed Points*

NONPOLYNOMIAL EXPANSION NEAR FIXED POINTS

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Characterization of chaotic behaviour in dynamical systems is usually done by calculation of the Lyapunov exponent spectrum. Achieving this characterization without recourse to numerical procedures is desirable from the point of the absence of numerical errors, but is difficult and tricky. There has been an attemp to overcome this limitation via a normal form approach. However, convergence of the normal form expansion is not guaranteed if the system does not admit an additional Lie Symmetry. It also requires that, in order to devise a meaningful approximation scheme, nonlocal structures must be considered. One obvious approach is averaging, this can only be applied to a limited class of systems. Non-polynomial expansions near fixed points based on singular functions posessing branch cuts have also been proposed.

In this work, the possibility of fractional expansions in the vicinity of fixed points of a dynamical system is investigated. A fractional transformation which, like the regular normal form expansion keeps the linear terms invariant in the first order and introduces additional terms in higher orders is proposed. In restricted cases resonant terms in higher orders can be removed. Furthermore, in certain workbench chaotic systems, convergence would be improved.

We investigate autonomous, continuous time, dynamical systems given by the set of differential equations $\dot{x} = v(x)$, where $x \in R^n$, $t \geq 0$, $v: R^n \rightarrow R^n$. We wish to consider the system near its fixed points x_0, given by $v(x_0) = 0$. Without loss of generality, one can move the fixed point to the origin.

A fractional near identity transformation $x_i = \frac{u_i + h_{i2}(\{u_k\})}{1 + \sum_j a_j u_j}$, where $a = \{a_j\} \in R^n$, is applied to a dynamical system, the linear terms is not affected, while the equation for eliminating the second order terms will be $Dh_i(y)J(y) - Jh_i(y) = F_i(y) + u_i a_j Ju$. Except for the last term on the right hand side, this is the same as the regular normal form expansion. Applications of this transformationin possible resonance cancellation and improved convergence are presented.

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Topic: 4

Title: *Self-Organized Criticality and Deterministic Chaos in a Generalized Spring-Block Model of Earthquake Faults: Analytical and Numerical Results*

Summary

SELF-ORGANIZED CRITICALITY AND DETERMINISTIC CHAOS IN A GENERALIZED SPRING-BLOCK MODEL OF EARTHQUAKE FAULTS: ANALYTICAL AND NUMERICAL RESULTS

Peter HAEHNER
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The classical spring-block model of earthquake faults proposed by Burridge and Knopoff (BK) is generalized in a way to account for an irreversible deformation (breaking of asperities) of the fault interface in addition to the rigid sliding displacements of the blocks. By this generalization the driving forces are allowed to relax, and a rate- and state dependent friction with velocity softening is introduced. The model exhibits a new kind of short-wavelength instability, which is associated to microfissuration during aseismic creep and by means of which parts of the fault self-organize to the critical state defined by the onset of velocity softening. The model is discussed in relation to the BK model (where this type of instability is absent) and compared to cellular automaton models exhibiting threshold dynamics and self-organized criticality. Numerical results show clustering of rupture propagation events (intermittency of the seismic cycle) and give power-law scaling of the event-size distributions (scale invariance as described by the Gutenberg-Richter law). Implications of the model with respect to the predictabilty of earthquakes are discussed.

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Topic: 2
Title: *Micromechanics of Damage in Composite Materials*
Summary

MICROMECHANICS OF DAMAGE IN COMPOSITE MATERIALS

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The primary damage in composites materials is in the form of many microcracks which may occur in the matrix, the reinforcement and at the interface. There two major problems to be considered. (1) Evaluation of effective property changes due to cracking, (2) Prediction of crack density. Some approaches to problem (1) and results are obtained are discussed. A novel approach to (2) based on energy balance is discussed with applications to interface debonding in composites and laminate cracking prediction.

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Topic:7
Title: *Asymptotic Crack Tip Fields for Dynamic Crack Growth in Ductile-Porous Solids*
Summary

ASYMPTOTIC CRACK TIP FIELDS FOR DYNAMIC CRACK GROWTH IN DUCTILE-POROUS SOLIDS

Bernd Potthast and Klaus P. Hermann
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In this paper, the asymptotic crack tip fields for fast running cracks in pressure sensitive,ductile-porous solids are determined. Two models are adopted for the constitutive description of the material. In particular, reference is made to the Drucker/Prager and Tvergaard/Needleman yield criterion [1,2] with associative flow associative flow laws. The second Model is an extended version of the Gurson model.

The asymptotic stress and velocity crack fields are numerically obtained for the case of the incremental theory, a stationary crack growth, plane stress conditions and mode I-loading. Further assumptions are linear isotropic hardening for the Drucker/Prager model and combined isotropic /kinematic hardening for the Tvergaard/Needleman model. Therefore, the first model proves to be suitable to describe a simple pressure sensitive behaviour of the material and the second model characterises a material behaviour containing porosity and strain hardening, ie. the Bauschinger effect. In the model of Tvergaard/Needleman the portion of porosity is described by a time dependent parameter. Due to the stationary conditions the calculations are carried out for a constant fraction of porosity.

Both mentioned hardening rules have been transferred to the elastic-plastic model of a crack tip surroundings of a stationary growing crack.

Crack tip fields in solids show a singular behaviour at the crack tip. The strength of this singularity depends decisive on the crack tip velocity [3]. A focus is to establish dependencies between the parameters describing the models of Drucker/Prager and Tvergaard/Needleman, respectively, and the elastic-plastic crack tip fields. These parameters are in detail the mixed hardening parameter of the corresponding model, the volume fraction of porosity, the parameters describing the portion of pressure sensitivity, the crack tip velocity, the strength of the singularity of the crack tip field and the sizes of the elastic and plastic zones in the crack tip surroundings.

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[3] Achenbach, J. D; Kanninen, M. F; Popelar, C. H: *Crack-tip fields for fast fracture of an elastic-plastic material*. J. Mech. Phys. Solids 29 (1981) 211-225.

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Topic: 2
itle: *Two Phase Flow in Porous Media : The Problem of Residuals*
Summary

TWO PHASE FLOW IN POROUS MEDIA : THE PROBLEM OF RESIDUALS

R. Hilfer
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and
Universitat Mainz,Mainz, Germany

The problem of trapping and mobilization of nonwetting fluids during immiscible two phase displacement processes in porous media is not only of great practical importance. It represents also a central unresolved issue in the current theoretical understanding of porous media physics. The problem is readily apparent from plots of the so called capillary desaturation curves or capillary number correlations. These curves display the residual saturations against the microscopically defined capillary number. If one interprets these microscopic capillary numbers as the ratio of viscous to capillary forces the breakpoint in experimental curves occurs at much too low values. One is forced to conclude that the capillary number does not represent the macroscopic force balance. The presentation will discuss a recent resolution of this paradoxical situation [1,2]. It will be shown that replotting the data against a novel macroscopic capillary number resolves the problem and the breakpoint occurs at unity in agreement with experiment.

[1] R. Hilfer and P.E. Oren, Transport in Porous Media, 22, 53 (1996)
[2] R. Hilfer, Advances in Chemical Physics, vol XCII, 299, 1996

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Topic: 2
Title: *The Theory of Thermo-Micromorphic Models of Damage Mechanics and its Applications*
Summary

THE THEORY OF THERMO-MICROMORPHIC MODELS OF DAMAGE MECHANICS AND ITS APPLICATIONS

Prof. Dr. Esin INAN
Istanbul Technical University, Istanbul, TURKEY

We considered the damage process as the generation and the growth of microdefects and describe the damaged solid as a micromorphic continuum. To take into account the thermal effects and apply to the practical engineering problems we made some simplifications in the theory and defined the damaged solid as a thermo-microstretched body as a special case of micromorphic continue. Then we applied the resulting equations to a simple bending of a beam to show the effects of temperature chances on the damage distribution along the height of the beam.

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Topic: 2-7

Title: *Bounds of Physical Properties of Some Random Structures Models*
Summary

BOUNDS OF PHYSICAL PROPERTIES OF SOME RANDOM STRUCTURES MODELS

Dominique JEULIN
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Fontainebleau, France

Bounds of the physical properties of random composites (like the dielectric permittivity, the thermal conductivity or elastic properties) are usually obtained from the combination of a variational principle and of statistical information summarizing the morphology of the random medium.

Third order bounds, involving the three point correlation functions were derived in the general case by M. Beran, and were later specialized by M. Miller, G. Milton and others to the case of two-phase random composites. In this last case, results are available for some types of random sets (i.e. two phase) models.
For materials with a continuous variation of properties (such as polycristals or materials presenting gradient of properties like microstructures with segregations), that can be modeled by random functions instead of random sets, very few results are available in the literature. However these happen to appear in many cases, the most simple one being the case of two phase composites with an interface presenting a different physical property (third phase).

We intend to present derivations of third order bounds for various types of random functions models corresponding to different micro geometrical arrangements. Some of them combine in various ways a Poisson point process and a primary random function to generate a broad variety of textures. The bounds obtained in this general situation offer new results that are of interest to compare the expected macroscopic response of various continuous textures.

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Topic: 2-GL
Title: *Some Basic Problems in Micromechanics of Solids with Pores of Various Shapes (dry and fluid-filled)*
Summary

SOME BASIC PROBLEMS IN MICROMECHANICS OF SOLIDS WITH PORES OF VARIOUS SHAPES
(DRY AND FLUID-FILLED)

Mark L. KACHANOV
Tufts University, Medford, USA

Three classes of problems will be addressed:

(1) Effective elastic properties of solids with pores of various shapes (including mixtures of diverse shapes). Identification of the proper parameters of defect density becomes important and non-trivial in this problem. Cracks, as a special case.

(2) Likely microfracturing patterns in a mixture of pores of diverse shapes.

(3) Pores and cracks filled with compressible fluid.

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Topic: 2-5
Title: *Micromechanics of Plastic Deformations, Continuum Damage and Necking*
Summary

MICROMECHANICS OF PLASTIC DEFORMATION, CONTINUUM DAMAGE AND NECKING

Vratislav KAFKA
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Structures of metallic materials can be very different, but their macroscopic stress-strain diagrams are qualitatively very similar. In our mesoscopic description the reason for it turns out very clearly: There always exist domains with regular lattice and plastic easy glide, and resisting barriers. Such a structure is modeled as a two-phase material with one phase elastic-plastic, the other phase elastic. The resulting model gives the typical elastic-plastic stress-strain diagrams on the macroscale. If some extent of small deformations is exceeded, the barriers are more and more broken through by plastic deformation and their continuity decreases. This process is described as a special kind of continuum damage, in which macroscopic Young's modulus does not change appreciably. The continuity of the elastic substructure of barriers conditions the homogeneity of macroscopic deformation and the possibility of increase of Cauchy stress. If this continuity is violated to some degree, the Cauchy stress cannot increase any more, macroscopic deformation ceases to be homogeneous, and necking begins. In the neck, the violation of continuity of barriers further proceeds and in the end it results in disintegration of the sample. This whole process

is modeled in a unitary way that makes it possible to describe the macroscopic stress-strain diagram up to rupture, the changes of shape of the sample due to necking, the course of local density of stored energy in the sample with neck, and the course of the value of the quantity 'degree of damage' that changes from zero to unit, but is not connected with any change of Young's modulus.

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Topic: 2
Title: *Self-Consistent Schemes in the Problem of Wave Propagation Through In Homogeneous Media*
Summary

SELF-CONSISTENT SCHEMES IN THE PROBLEM OF WAVE PROPAGATION THROUGH INHOMOGENEOUS MEDIA

S.K. Kanaun
Zaragoza, MECHICO

The comparative analysis of two main self-consistent schemes (the affective field and effective medium methods) in application to the problem of wave propagation through inhomogeneous medium is presented. Both the methods have long histories and now they exist in the form of several different versions. The main advantage of the methods is that they reduce the many particle problem (the problem of interaction between many inclusions in composite media) to the one particle problem. In the frameworks of the methods this reducing is realized with the help of some hypotheses that cannot be strictly proved. The main hypothesis of the effective field method is that every inclusion in the composite behaves as isolated one in the background medium (matrix) and the existence of the surrounding inhomogeneities is taken into account via the effective external field that acts on this inclusion. In the effective medium method it is assumed that for the construction of the field inside any inclusion in the composite the inhomogeneous medium outside some vicinity of this inclusion may be changed for a homogeneous medium with effective properties of the composite.

An evident way to estimate the areas of application of every method is the comparison of their predictions with experimental data. But for dynamics in literature exist only scanty such data that do not cover desirable areas of frequencies of exiting field, properties and volume concentrations of inclusions. Thus it is important for applications to have a grasp of the region of the parameters of inhomogeneous media

where the methods give physically correct results and to have a view of quantitative differences between the predictions of the various versions of the methods. Such a quantitative comparison is done in this work for the case of electromagnetic wave propagation through media with sets of isolated spherical inclusions. Both the methods are applied for the calculation of the phase velocities and attenuation factors of the mean wave field in such composites when the exciting field is a plane monochromatic wave. The cases of optically hard ($\varepsilon/\varepsilon_0=10$) and optically soft ($\varepsilon/\varepsilon_0=0.1$) inclusions are considered. Here ε is the dielectric property of inclusions, ε_0 is such a property of the matrix. The volume concentrations of inclusions are in the region $0<p<0.5$ and the lengths of the exiting wave field are changed in the region $0<k_0R_0<10$, where k_0 is the wave number of the matrix, R_0 is the mean radius of inclusions.

The analysis of the obtained results allow us to evaluate the area of applications of the methods, to detect the sources and orders of possible errors. Some general conclusions of the present analysis are valid for other tips of waves (acoustic and elastic) in the inhomogeneous media with the considered microstructure.

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Mr. Oncu KAYALAR(Special poster session for young researchers)

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Topic: 1
Title: *Scaling behaviour in the dynamics of pinned interfaces with inertia*
Summary

SCALING BEHAVIOUR IN THE DYNAMICS OF PINNED INTERFACES WITH INERTIA

Oncu KAYALAR *and* Ayşe ERZAN
Istanbul Technical University, Istanbul, Turkey

The Sneppen model and invasion percolation are modified to include an effective inertia. The roughness exponent is found to depend on the inertia; however, the dissipative nature of the motion is unaltered so that the center of mass of the front continues to be displaced with constant velocity in the asymptotic regime.

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Topic: 4
Title: *Surface and Interface Waves in Crystals and Multicrystal Systems*
Summary

SURFACE AND INTERFACE WAVES IN CRYSTALS AND MULTICRYSTAL SYSTEMS.

Arnold M.KOSEVICH
B.Verkin Institute for Low Temperature Physics, Kharkov, URAINE

Simple discrete lattices with free surfaces or plane defect layers are considered as examples of the systems possessing the vibrations localized at the free surface or planar defect. Using the long-wave approximation the dynamic equations for the lattice vibrations are written in the form of differential equations, typical for continuum description of elastic media. It is shown that there exist the high frequency localized waves in such systems besides the low frequency surface vibrations like the Rayleigh waves, which are usually studied in the theory of elasticity.

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Topic:
Title: *Continuum Dynamic Theory of Elastoplastic Medium with Microstructure*
Summary

CONTINUUM DYNAMIC THEORY OF ELASTOPLASTIC MEDIUM WITH MICROSTRUCTURE

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and
E. Kröner
University of Stuttgart, Stuttgart Germany

A special case of elastoplastic media is considered, in which the internal stresses created in the course of deformation can be characterised by a definite length parameter, which does not change in the course of plastic deformation. The very existence of such a length parameter can only be due to the presence of some internal structure, which defines the overall character of the inhomogeneties of plastic deformation and internal stresses. WE therefore speak about a microscopically inhomogeneous medium or a medium with microstructure. It is shown that for this class of materials a macroscopic (continuous) description can be developed which takes into account both the macroscopical mechanics of material and its internal structure.

The energy of a medium with microstructure can be represented as a sum of terms coming from the macroscopical and microscopical stresses correspondingly:

$$E = E^{macro} + E^{micro} \tag{1}$$

The first term is a function of the (macroscopic) tensor of elastic deformation. If there is only one glide system in the medium, and the distances between the neighbouring glide planes do not change during the plastic deformation, the second term can be represented as a function of the macroscopic dislocation density tensor. The whole energy then takes the form:

$$E = E^{macro}(\bar{\varepsilon}^{el}) + E^{micro}(\bar{\alpha}) \tag{2}$$

where and $(\bar{\varepsilon}^{el})$ are $(\bar{\alpha})$ correspondingly the macroscopic tensors of elastic deformation and dislocation density. We refer to the paper where it was proposed to use these quantities as independent dynamic variables of a crystalline medium. The general equilibrium equations are also be found in[1].

The energy density U corresponding to any glide system is calculated as

$$U = \frac{E^{micro}}{V} = \frac{G(2d)^2}{24} n_k n_m e_{ikl} e_{jmn} \times (\bar{\alpha}_{ni}\alpha_{lj} + \delta_{ln}\alpha_{pi}\alpha_{pj} + \frac{2\upsilon}{1-\upsilon}\bar{\alpha}_{li}\bar{\alpha}_{nj}) \tag{3}$$

where $2d$ is the distance between the glide planes, $\bar{\alpha}_{ij}$ is the macroscopic dislocation density, $\mathbf{n}$ is the normal unit vector, determining the glide system, G is the shear modulus.

The complete energy of the microstresses in the medium is given as a sum over all glide systems.

In general case of the macroscopically nonhomogeneous dislocation distribution the potential energy of the medium can be written down in the form

$$E = \int \frac{1}{2} C_{ijkl} \bar{\varepsilon}^{el}_{ij}(\mathbf{r}) \bar{\varepsilon}^{el}_{kl}(\mathbf{r}) dV + \int \frac{1}{2} a_{ijkl} \bar{\alpha}_{ij}(\mathbf{r}) \bar{\alpha}_{kl}(\mathbf{r}) dV \tag{4}$$

where C_{ijkl} is the tensor of elastic moduli of the medium and a_{ijkl} is the corresponding tensor for the momentum stress.

The kinetic energy K of the system with microstructure can be expressed analogously to the potential energy (1) as a sum of macroscopic and microscopic parts:

$$K = K^{macro} + K^{micro}, \tag{5}$$

where

$$K^{macro} = \int \frac{\rho \dot{\mathbf{u}}^2}{2} dV$$

$$K^{micro} = \int \frac{1}{2} B_{ijkl} \dot{\beta}_{ij} \dot{\beta}_{kl} dV \tag{6,7}$$

Here ρ is the mass density of the medium, $\mathbf{u}$ is the vector of total displacements, β_{ij} is the tensor of plastic distortion, and B_{ijkl} are coefficients describing the inertial

properties of the micro-motions in the medium. These are connected with the motion of dislocations (eg. local rotations). The coefficients B_{ijkl} are calculated in the paper for two special moving dislocation arrangements, namely for purely edge and purely screw dislocations moving along the glide planes.

It is shown that both the kinetic and potential microscopic parts " of the energy are not sensitive to the exact distribution of dislocations in the glide planes and, as a matter of fact, can be interpreted at the mesoscopic" level of rather than on the microscopic level of individual dislocations.

The potential and kinetic energies known, the Lagrangean and the dynamic equation of the medium can be easily written down. These will describe an idealised medium with no dissipation. Then the energy dissipation can be taken into account by introducing friction forces into Lagrangean equations using a dissipative function.

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Topic: 2
Title: *Buckling of Composite Plates the Material of Which Has Periodically Curved Structure*
Summary

BUCKLING OF COMPOSITE PLATES THE MATERIAL Of WHICH HAS PERIODICALLY CURVED STRUCTURE

Zafer KUTUĞ
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The investigation of the problems of buckling of the plate fabricated from the composite materials has major significance both from the viewpoint of the development of fundamental investigations of plate theory and from the viewpoint of applications to specific plates, which are used, in various areas of modern technology. In numerous papers related to the plates fabricated from the layered composite materials, using continuum approach in which the piecewise-homogeneous material of plates has been changed by homogeneous anisotropic material with normalised mechanical properties has made the investigations, and the various refined plate theories have been used. In these cases, the layered composite plates have generally been considered as if their layers are ideal, ie. they are parallel to mid-plane of the plate. But, in practice, layers of plates have some curving due to producing process or designing.

In this study, the effect of periodically curved layers on buckling of the simply supported composite rectangular plate bounded such as $\{0 \le x_1 \le l_1 ;\ -h/2 \le x_2 \le h/2 ;\ 0 \le x_3 \le l_3\}$ has been examined. Continuum theory

of which Akbarov and Guz' had proposed for such materials is used in this investigation. Stability equation of plate has been established by using three-dimensional linearized elastic stability equations. Due to the curving in plate structure, the stability equations of composite plate have variable coefficients. For consistency of boundary conditions of plate, Galerkin's Method has been used. Additionally, Kromm's refined plate theory which takes into consideration the transversal shear strain in the plate section has been used in the study and the influence of the structural parameters of plate material to the critical values of the external forces are investigated.

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Topic: 5
Title: *Dissipative Driving Force in Ductile Crystals and the Strain Localization Phenomenon*
Summary

DISSIPATIVE DRIVING FORCE IN DUCTILE CRYSTALS AND THE STRAIN LOCALIZATION PHENOMENON

K. C. Le, H. Schütte and H. Stumpf
Ruhr-Universitat Bochum, Germany

This paper is concerned with crystals undergoing large plastic deformations. The free energy per unit volume of the reference crystal is supposed to depend on the elastic distortion as well as on constant tensors characterizing the crystal symmetry. The dissipative driving force is shown to be equal to the Eshelby stress tensor relative to the reference crystal. For single crystals obeying Taylor's equation the driving force reduces to the Eshelby resolved shear stress, which is power-conjungate to the slip rate. The Schmid law formulated with respect to the latter is used to determine the critical hardening rate at the onset of the shear hand formation.

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Topic: 2
Title: *The Fiber Reinforced Piezoelectric Composites for Damping Application*
Summary

THE FIBER REINFORCED PIEZOELECTRIC COMPOSITES FOR DAMPING APPLICATION

Valery LEVIN
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There are many applications in technics where the addition of passive vibration damping to a structural system can increase the system performance or stability. The most common way to produce a structural damping is addition the viscoelastic elements or attachment of some other mechanical vibration absorber to the structure. Recently the new type of passive damping mechanism for structural systems has been developed. This mechanism is based on the using the composite material consisting of a polymer matrix reinforced by the piezoelectric continuous fibers covered with a thin layer of electroconductive material (shunted fibers). This coating forms a passive electrical circuits designed to dissipate the electrical energy which has been converted from mechanical energy by the piezoelectric fibers. Such materials possess frequency dependent stiffness and loss factor which are also dependent on the shunted circuit.

In this communication a variant of self-consistent scheme (effective field method) is used for theoretical description of effective electric and elastic properties of such materials taking into account electroelastic coupling. According to the main assumption of the method each coated fiber in composite is considered as isolated in homogeneous matrix. The presence of surrounding fibers is accounted for trough a local external electric and elastic fields applied to the fiber. The self-consistent conditions allow to obtain a system of integral equations for the effective external fields. The statistical averages of these fields are calculated under certain general assumption about the geometrical structure of a set of fibers. As result the explicit formulas are obtained for the several effective electroelastic constants of composite materials reinforced by the shunted piezoelectric fibers. The obtained expressions are used then for the consideration of the plane longitudinal waves propagation. The real and imaginary parts of the wave number of these waves are found in dependence on the frequency and the components electroelastic properties. These quantities characterize the wave velocity dispersion and attenuation.

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Topic: 1
Title: *The Mass Transport by Convection and Diffusion in a Multiporous Medium*
Summary

THE MASS TRANSPORT BY CONVECTION AND DIFFUSION IN A MULTIPOROUS MEDIUM

Diana BALTEAN [1][2], Therese LEVY[1], Stefan BALINT[2]

(1) LMM U. M. R. 7607, Universite Paris 6 et C. N. R. S.
(2) universitatea de Vest din Timisoara

The aim of this paper is to develop a macroscopic model for a passive solute transport in a heterogenous medium, consisting of impervious solids periodically distributed in a porous matrix. In the porous part the flow is described by the Darcy's law. The macroscopic equations governing the average concentration field in the macroscopic parameters are obtained. A homogenization technique (a double scale asymptotic analysis) is used, the small parameter a being the ratio between two characteristics lengths l (the period scale) and L (the sample scale).

The case of small concentration of the solid inclusions is analysed.

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8. J. .C. Wodie: **Contribution a l'étude des millieux poreux par la methode de l'homogeneisation**, These de doctorat de l'Universite Paris 6 (1992)

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Topic: 2-GL
Title: *Recent Advances in Suspension Mechanics*

Summary

RECENT ADVANCES IN SUSPENSION MECHANICS

Daniel LHUILLIER
Universite Pierre et Marie Curie, Paris, France

The lecture will focuss on some recent trends in the macroscopic description of suspensions of particles.

- Pseudo-turbulence : The hydrodynamic interactions between particles lead to important fluctuations of the fluid and particles velocities. These fluctuations must be somehow incorporated into the macroscopic description to explain phenomena such as hydrodynamic diffusion. The talk will present the ideas developed by Buyevich, Batchelor,Koch ...

- Ensemble averaging in non-uniform suspensions : the statistical approach of suspensions, with a probability distribution function for the various possible particle configurations, needs some care when applied to a suspension displaying a non-uniform particle concentration for instance. As a result one is now able to link the test-particle approach with the ensemble averages. The lecture will present results by Buyevich, Zhang and Prosperetti and the author.

- Ultracentrifugation of suspensions : When particles have not an evenly distributed mass and present themseves as mass dipoles, a certain number of surprising phenomena occur when the particles are submitted to a spatially dependent centrifugal field. We will present results obtained by Brenner
and collaborators.

- Thermodynamics of colloidal suspensions : This more physico-chemical aspect of the dynamics concerns suspensions of particles with micron size. We will report on the thermodynamic force as a natural generalization of the osmotic pressure force, and we will comment on how Fick's law must be modified in case of colloidal suspensions.

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Topic: 5-GL
Title: *Generalized Plasticity: Theory and Application*
Summary

GENERALIZED PLASTICITY: THEORY AND APPLICATION

Jacop LUBLINER
Berkeley University, USA

A mathematical formulation of some fundamental postulates of plasticity (defined as rate-independent inelasticity with loading-unloading irreversibility) leads to the concept of generalized plasticity, of which classical plasticity is a special case. Some specific, simple models of generalized plasticity (including thermal properties) are applied successfully to the description of the behavior of such materials as graphite and shape-memory alloys.

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Topic: 2

Title: *Material Mixing in Space-Time: The Problem of Bounds for Effective Properties*

Summary

**MATERIAL MIXING IN SPACE-TIME:
THE PROBLEM OF BOUNDS FOR EFFECTIVE PROPERTIES**

By Konstantin A. LURIE
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The role played by composites in the material design and optimization is well understood in statics. This role should be no less significant in dynamics where composites may arise due to the material mixing in space-time. This type of mixing occurs when both inertial and stiffness parameters alternate on a fine scale and thus demonstrate chattering. A transmission line with properly activated linear inductances and capacitances may serve as an example.

Another reason that may cause fast periodic material patterns may be the actual relative motion of the pieces of material occupying alternating cells in space-time. This latter situation arises, for example, in the context of electromagnetic wave propagation in dielectrics when the dielectric material is exposed to a high frequency background mechanical vibration in the form of standing waves.

With regard to spatio-temporal composites, there arises a G-closure problem just as it arose before in a similar elliptic situation. G-closure is defined in this context as the set of all possible spatio-temporal composites assembled from the given constituents. The G-closure is an invariant characteristic of a mixture, and therefore it should be

specified in suitable covariant terms. Such a description is well known in statics; the purpose of the talk is to show how it may be accomplished in dynamics, particularly in electrodynamics of moving dielectrics, for a typical hyperbolic equation of the 2nd order with coefficents variable in space-time.

Some features of a G-closure will be revealed in the case of one-dimensional wave propagation. Specifically, it will be shown in this context that a spatio-temporal mixture of two dielectrics possessing the same value of the ratio of their dielectric permittivity to their magnetic permeability, will have the same ratio of its relevant effective parameters. This is a hyperbolic analog of the conservation law widely known for two-dimensional polycrystals in statics.

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Topic:

Title: *On a two-point Correlation Function in Random Dispersions and some Applications*

Summary

ON A TWO-POINT CORRELATION FUNCTION IN RANDOM DISPERSIONS AND SOME APPLICATIONS

Konstantine Z.Markov
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For a random dispersion of identical spheres the function $F^{pc}(y_1 - y_2)$ -the ``particle-center" correlation---is considered in detail. This is the probability density of finding y_1 in a sphere and y_2 in a sphere's center. A simple integral representation of $F^{pc}(y)$ through the radial distribution function is first proposed. It allows us to derive closed form expressions for statistical quantities in which $F^{pc}(y)$ features. The employed arguments can serve as a model when studying the known and more refined two-point correlation like ``surface-particle" and ``surface-surface" ones.

As a simplest application of the obtained results the classical Smoluchowski problem, concerning steady-state diffusion of a species among an array of nonoverlapping and ideally absorbing sinks, is revisited. Using the variational principle of Rubinstein and Torquato (1988), a lower estimate on the effective sink strength k^{*2}, in which $F^{pc}(y)$ shows up, is obtained in an elementary manner. It turns out that the estimate *coincides* with that of Doi (1976) or Talbot and Willis (1980), but here neither more complicated "surface" correlations, nor Hashin-Shtrikman's type principles are invoked. The reasoning clearly indicates the way how the above mentioned estimates can be generalized, taking into account the ``particle-surface" and ``surface-surface" correlations.

The 2D counterpart of the correlation function $F^{pc}(y)$ is discussed as well, together with the appropriate variational reasoning. This allows us to offer in passing a certain explanation why the Talbot and Willis' scheme *fails* to produce a nontrivial lower estimate on k^{*2} in the 2D case.

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Topic: 1
Title: *Hardening Treated as Phase Transition: A Model based on Superconductivity*
Summary

HARDENING TREATED AS PHASE TRANSITION: A MODEL BASED ON SUPERCONDUCTIVITY

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The different stages (elastic, easy glide, stage II and III) which a single crystal under external stress presents, are due to the different densities and distribution of moving dislocations during the deformation. Dislocation density is not changed by a compatible deformation and therefore the extent of each of the different stages is invariant under such a deformation. With this invariance as gauge principle, a model is presented to describe as phases the different plastic stages of a crystal. The first step to build up such a model is to formulate a gauge theory for mobile dislocations in complete analogy with the Maxwell theory of electromagnetism. The corresponding gauge principle is the invariance of a plastic stage on a compatible deformation. Density of mobile dislocations and dislocation current are analogous in this model to the magnetic and electric field, and the analogous to the electric current and charge density in the electromagnetism are here the external stress and the slip velocity of the crystal layers during the plastic deformation. In a second step, the gauge fields corresponding to the density of mobile dislocations are coupled to an order parameter. A partition function for this model is estimated in order to study the different stages as phases of the dislocation system. Depending on the strength of the couping constant and on the condensation state of the order parameter, the model presents four different phases, each one with properties similars to the different stages of the plastic deformation of a single crystal, including the absence of the stage II at high temperatures.

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Topic: 3
Title: *Elements of a Theory of Material Growth*
Summary

ELEMENTS OF A THEORY OF MATERIAL GROWTH

M. Epstein (Calgary, CANADA)
and
G. A. Maugin (Paris FRANCE)

In this attempt at developing a theory of diffusive material growth (mass creation or resorption such as in living organisms), the latter is viewed as a local rearrangement of material inhomogeneities described by means of first-and second-order uniformity >, the first of these having possibly a determinant larger than one. Accordingly, in agreement with the general theory of material uniformity and inhomogeneity (Noll, Wang) and its most recent developments (Epstein-Maugin, 1990 on), an essential role is played by the balance of canonical (material) momentum-ie., the balance of momentum on the material manifold, in which the flux associated to canonical momentum is the so-called Eshelby material stress tensor. Growth is shown to develop a force source of quasi-inhomogeneity of its own in this equation. The corresponding irreversible thermodynamics is expanded. If the constitutive theory of basically elastic materials is only first-order in gradients, the diffusion of mass growth cannot be accommodated, and volumetric growth then is essentially governed by the inhomogeneity velocity "gradient" (first-order transplant theory) while the driving force of irreversible growth is shown to be Eshelby stress or, more precisely, the "Mandel" stress (already introduced in some invariant theories of finite-strain elastoplasticity) -although the possible influence of "elastic" strain and its time rate is not ruled out. Restrictions imposed upon the growth evolution equation by (I) uniformity of the material, (ii) so-called "G-covariance", (iii) frame indifference, and (iv) material symmetry, are carefully implemented, yielding a rather simple and reasonable evolution law. In the second-order theory which does allow for growth diffusion, a second-order inhomogeneity tensor -related to the difference between two connections-need be introduced; but it is possible to envisage a special theory where the time evolution of the second-order transplant is slaved to that of the first-order transplant, avoiding thus insuperable complications. The geometrical background of the theory is developed in both cases, although not in an abstract way, within the finite-deformation framework. The second-order theory is based on the notion of so-called G-structures of differential geometry.

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Topic: 2
Title: *Presence and Texture in Complex Continua*

PRESENCE AND TEXTURE IN COMPLEX CONTINUA

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Bodies with diffused voids or fractures may be given a convenient homogenized representation without lacunae or discontinuities, where trace of the complex substructure is preserved through a scalar field of 'presence' and tensorial fields of 'texture'. In our paper 'A sigma algebra and a concept of limit for bodies' we offered examples obtained through limit processes. Here the study is carried on and the influence of the above mentioned fields on balance and constitutive equations is explored.

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Topic:
Title: *Effects of Densely Packed Substructures On the Responces of a Core Structure*
Summary

EFFECTS OF DENSELY PACKED SUBSTRUCTURES ON THE RESPONSE OF A CORE STRUCTURE

John J. McCoy
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A structural system comprised of a core structure to which a large number of passive substructures are attached, raises many research issues. Amongthese are: (1) the modeling of the effects of each individual substructure, in thelimit in which the connection region is small, (2) across-length-scale coupling occasioned by a large number of densely packed substructures, and (3) a lack of a complete description of the substructures and their packing. Some recent results that apply to each of the

issues will be described. The recently presented theory of multiresolution decomposition using wavelets will be highlighted in the context of the last two issues.

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Topic: 5
Title: *An End Effect Model for Fibre-Reinforced Composites*
Summary

AN END EFFECT MODEL FOR FIBRE-REINFORCED COMPOSITES

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The current composite materials literature offers a rich collection of stress concentration end effects in fibre-reinforced composites and of corresponding estimates of ineffective (load transfer) lengths. Generally, the models reduce the end effects to interfacial shear stress distributions of intensities which are either constant along the ineffective fibre portions or increase when fibre ends are approached. The vitally important for composites behaviour phenomena of plastification of phases and/or of their debonding are viewed by these models as being governed by simple yield and/or fracture criteria based on critical shear stress values such as shear yield stresses and/or shear strengths only. The models assume thus that high interfacial shear stressses develope close to fibre ends but neglect, at the same time, the considerable drops that the same stresses should undergo along certain end fibre portions due to the fact that fibre end surfaces are, as a rule, practicaly stress free.

The present study completes in a natural way these more or less realistic models with a model of the effect associated with such shear stress changes. The effect is shown to be quite specific. It concerns only thin layers adjacent to fibre ends and creates in these layers a specific state of complex bending with a corresponding standard stress field. The most distinguishing feature of this local field is the change in sign of the radial interfacial stresses very close to fibre ends and the high intensity that the same stresses achieve at the very fibre ends.

The model proves thus that this local stress concentration field is a decisive factor for actual onset (and further development) of plastic yield and/or fracture phenomena. It indicates, in addition, that the criteria governing these phenomena should be much more precise than the commonly adopted ones and based, first of all, on the specific features of the same stress field. The quantitative estimates of these features derived in the present study provide a sound basis for constructing such advanced criteria.

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Topic: 2
Title: *Exact Relations for Composites: Towards a Complete Solution*
Summary

EXACT RELATIONS FOR COMPOSITES: TOWARDS A COMPLETE SOLUTION

Y.Grabovsky, G.Milton *and* D.Sage
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Typically, the elastic and electrical properties of composite materials are strongly microstructure dependent. So it comes as a nice surprise to come across exact formulae for (or linking) effective moduli that are universally valid no matter what the microstructure. Such exact formulae provide useful benchmarks for testing numerical and actual experimental data, and for evaluating the merit of various approximation schemes. Classic examples include, Hill's formulae for the effective bulk modulus of a two-phase mixture when the phases have equal shear moduli, Levin's formulae linking the effective thermal expansion coefficient and effective bulk modulus of two-phase mixtures, and Dykhne's result for the effective conductivity of an isotropic two-dimensional polycrystalline material. Here we present the first systematic theory of exact relations embracing the known exact relations and establishing new ones. The search for exact relations is reduced to a search for tensor subspaces satisfying a certain algebraic condition. One of many new exact relations is for the effective shear modulus of a class of three-dimensional polycrystalline materials.

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Topic: 5
Title: *Elasticity of a Continuum with Extra-Matter and Dislocation Defects*

Summary

ELASTICITY OF A CONTINUUM WITH EXTRA-MATTER AND DISLOCATION DEFECTS

Faez Miri*, Nicolas Rivier** and Reza Khajehpour*

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Continuum elasticity in the presence of defects is best described by differential geometry, as a mapping between the actual and natural states of the material. Defects are distinct contributions to the incompatibility: disclination as a source of curvature, dislocation, of torsion, and inclusions, of extra matter.

We study a two-dimensional elastic continuum with extra-matter only. Furthermore, the extra-matter tensor takes a very simple form (integrable, or conformal Weyl geometry). As with dislocations, it is possible to absorb the most of the effects of this extra-matter tensor into standard Riemannian geometry, but not all. We investigate the physical, non-Riemannnian consequences of the presence of extra-matter, and interactions between extra-matter and dislocations.

Conformal crystals provide illustrations of the strain caused by various defects. We will give several examples (gravity rainbow, daisy, ferrofluid foam, bubble stem,...).

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Topic: 7
Title: *Continual, Discrete and Hybrid Models in Rupture Mechanics*
Summary

CONTINUAL, DISCRETE AND HYBRID MODELS IN RUPTURE MECHANICS

N.Morozov, M.Paukshto
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The problem is demonstrated on the base of main problem of crack's theory : the elastic plane with finite crack. The authors compare the wellknown discrete solutions of Dines, Paskin,Ortiz e ct. with continual solutions and hybrid solutions of V.Novogilov and R.Thomson. The model of R.Thomson and model of V.Novogilov are compared in detail. It is proved the identification the R-function of Novogilov and lattice function of Thomson. On the base of Thomson model it is proved the existence theorem of "fracture soliton". It is explaned the G.Cherny-V.Kozorezov effect of the loosing of resistance of medium.

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Topic: 2
Title: *Mesoscopic Modelling of Magnetization Process and Magnetostriction*
Summary

MESOSCOPIC MODELLING OF MAGNETIZATION PROCESS AND MAGNETOSTRICTION

Prof. Shinya MOTOGI
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A macroscopic theory using the internal variable theory and the analogy of plasticity is applied for the description of magnetization and magnetostriction of single crystal, and for polycrystal, a micro-mechanical approach such as self consistent scheme is adopted. The internal variable here is the volume fraction of magnetic domains transversely oriented to the magnetic field. Introducing this internal variable, we obtain many fruitful conclusion such as the appropriate description of magnetostriction, three dimensional magnetization curve, re-interpretation of magnetization hysteresis.

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Topic: 2
Title: *Asymptotic Analysis of Junctions*
Summary

ASYMPTOTIC ANALYSIS OF JUNCTIONS

O.SELSIL *and* A.B.MOVCHAN
Bath University, Bath,UK

We consider an elliptic boundary value problem in a singularly perturbed domain involving junctions. Examples include thin-walled honeycomb structures used in cathalytic combustor monoliths. We construct the asymptotic representation of solutions of boundary value problems of linear elasticity and steady-state heat transfer and present the accurate derivation of junction conditions. A particularly interesting application is in the analysis of thin-walled structure with thin surface layers.

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Topic: 7
Title: *Stress Singularity Exponent at the Vertex of a Three-Dimensional Conical Notch*
Summary

STRESS SINGULARITY EXPONENT AT THE VERTEX OF A THREE-DIMENSIONAL CONICAL NOTCH"

D.Esparza, N.V.Movchan
University of Bath, Bath ENGLAND, UK

The problem involves the study of three-dimensional singularities of elastic stress fields in domains with vertices and edges. We present the analysis of a spectral problem associated with asymptotic fields in the vicinity of a conical notch and evaluate the singularity exponents which characterize the behaviour of the solution close to the vertex.

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Topic: 2-GL
Title: *Some Microscopic Perspectives in Continuum Modelling*
Summary

SOME MICROSCOPIC PERSPECTIVES IN CONTINUUM MODELLING

Ian MURDOCH
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The utility of motivating continuum concepts and relations in terms of scale-dependent microscopic averages will be demonstrated without recourse to Statistical Mechanics. Examples will include the notions of material point, boundary, and stress tensor, with implications for mixture theory and porous media modelling. An outline of a modern statistical mechanical approach to balance relations will be sketched.

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Topic: 1
Title: *Endoreversible Thermodynamics: A Tool for Simulating Discrete Systems*
Summary

ENDOREVERSIBLE THERMODYNAMICS: A TOOL FOR SIMULATING DISCRETE SYSTEMS

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Endoreversible thermodynamics concerns with reversible sub-systems being in irreversible interaction with each other. Consequently endoreversible thermodynamics represents the analogue for discrete systems to the local equilibrium hypothesis in continuum thermodynamics. Here a real cyclic 2-reservoir process is simulated by endoreversible model processes, such as a heat leak process, a Novikov process, and a Curzon-Ahlborn process. Simulation means, that the simulating process has the same net heat exchanges, cycle time, power, entropy production, and efficiency as the original one. Additional restrictions with respect to the second law do not appear. The comparison of the efficiencies of the endoreversibly modelled process and the original one is not adequate for describing the quality of a process. Other coefficients are introduced.

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Topic: 1
Title: *Wave Propagation in Bounded Media without Using Boundary Conditions*
Summary

WAVE PROPAGATION IN BOUNDED MEDIA WITHOUT USING BOUNDARY CONDITIONS

D. F. Nelson
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A new mathematical method has been devised to solve for propagating waves inside and outside a bounded medium without any use of boundary conditions. The method applies to systems where the usually used boundary conditions are so-called natural boundary conditions, that is, ones derived from the propagation equations. For example, the electromagnetic wave equation and the Maxwell boundary conditions

form such a system. The usual approach of solving the wave equation in each medium and joining the solutions through the boundary conditions has been used successfully countless times. However, this approach has presented intractable problems for systems in which the wave interacts nonlocally with the medium. This can be understood physically as follows. In a nonlocal medium its response (e.g. the polarization) at a particular point depends on the value of the exciting field (e.g. the electric field) in a region around that point. As the point approaches the surface within the nonlocality range this region becomes truncated and the bulk response changes to a surface response whose value is not known a priore. Thus the field is not known just inside the medium and so its joining to the outside field can not be accomplished.

The new method completely sidesteps this problem by operating in wave vector space where there are no boundaries and where the transformed wave equation contains all the information that natural boundary conditions contain. The mathematical procedure is quite novel. The transformed wave equation is converted from an integral equation to an algebraic equation by a theorem, but at the expense of producing more dependent transform functions than equations. When the coefficient of each transform function is required to vanish at the wave vector where the transform blows up (to retain physical meaningfulness of the equation), the dispersion relation of each medium results. From their solutions the poles of each part of the transform are obtained and thus the general functional form of each part (containing a number of unknown constants) is obtained. Substitution of these forms back into the transformed equation then produces a polynomial for each component of the vector equation. The polynomial variable is the arbitrary wave vector variable and so vanishes only when the coefficient of each term vanishes. Those conditions are sufficient to determine all the unknown constants. Retransformation to real space completes the solution.

Applications of this method to several nonlocal (also called spatially or wave-vector dispersive) interactions are presented. The original application was to the ABC or additional boundary condition problem which considers the interaction of a light wave and a mobile exciton producing a second-order resonant wave-vector-dispersive interaction. A new expansion of this is to a phonon-mediated optical Stark effect produced by a pump wave near an exciton resonance and observed by a probe beam. Application to the age-old interaction called optical activity, which produces first-order wave-vector dispersion, yielded surprising results. Recently this development has been modified to give an explanation for specular optical activity in terms of a wave-vector-dispersive surface layer. Application of the method to multiple surfaces is also discussed.

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Topic: 5

Title: *Observations of Strain Localization and Instabilities in Plastic Deformation of Metals*

Summary

OBSERVATIONS OF STRAIN LOCALIZATION AN INSTABILITIES IN PLASTIC DEFORMATION OF METALS

Hartmut NEUHAEUSER,
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During plastic deformation of crystalline (and sometimes also of amorphous) materials under certain conditions transient instabilities occur which are intimately connected with localization of plastic strain and which may cause serrated yielding. After a brief overview, we will show micro- and macroscopic observations on such phenomena arising from different reasons, i.e. so-called type h instabilities (structural softening) accompanied byLueders band propagation, and type S instabilities (negative strain rate sensitivity) accompanied by Portevin-LeChatelier bands. The microprocesses and the mechanisms of deformation band propagation inferred from these observations will be discussed in particular.

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Topic: 2
Title: *On Homogenization*
Summary

ON HOMOGENIZATION

E.Turan Onat
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We are interested in macroscopically homogeneous materials that are locally heterogeneous and anisotropic. It is expected that in the analysis of average stresses and deformation in a body composed of such a material it should be possible, in most cases, to regard the material as a homogeneous continuum with appropriately chosen mechanical properties. It will be seen that certain assumptions that constitute a basis for this process of " homogenization" will not be valid near the boundary of the body and possibly in some other locations.

If one hopes to estimate local stresses and deformation by using the solution of the homogenized problem as a first step in a further analysis, one needs to take into account these limitations of homogenization.

The paper is devoted to a discussion of these difficulties and possible remedies for their resolution.

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Topic: 2
Title: *Micromechanics and Stochastic Finite Element*
Summary

MICROMECHANICS AND STOCHASTIC FINITE ELEMENTS

Martin OSTOJA-STARZEWSKI
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A large part of micromechanics has been concerned with establishment of effective moduli of heterogeneous materials in the continuum limit of a Representative Volume Element (RVE). As elucidated by Hill (1963), the RVE needs to be sufficiently `representative' of themicrostructure, and thus, considerably larger than a typical microscale length (e.g., grain size). A general method for determination of the convergence to the RVE in elastic materials is offered by a hierarchy of bounds stemming from Dirichlet and Neumann boundary conditions (Huet, 1990; Sab, 1992; Ostoja-Starzewski, 1994, 1996). Examples cover: two-phase composites (including the extreme limits of holes or rigid inlcusions), polycrystals, cracked materials and fibrous media. This need to take sufficiently large volumes corresponding to the RVE limit is contrasted with the requirement of taking ever smaller finite elements, in solving global boundary value problems by a finite element method (FE); this is done in order to match solutions based on minimum potential and complementary energy principles, respectively. As a result, unless the microstructre is sufficiently fine, both energy principles provide the bounds on the actual response while the finite element is, in fact, a meso-scale finite element (Ostoja-Starzewski, 1993, 1998). Given the randomness of the medium, this meso-scale element is a Statistical Volume Element (SVE), whose properties are described by probability distributions of two random fields defined by Dirichlet and Neumann boundary conditions. The possibility of an optimal SVE and the verification of global response bounds by micromechanics are also discussed.

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Topic:
Title: *The Stability of Poiseuille Flow of a Second Order Incompressible Rivlin-Ericksen Fluid*
Summary

THE STABILITY OF POISEUILLE FLOW OF A SECOND ORDER INCOMPRESSIBLE RIVLIN-ERICKSEN FLUID

Saadet ÖZER *and* Erdoğan ŞUHUBİ
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The analysis of instability in flows has concentrated mainly on newtonian fluids. More recently the stability on non-newtonian fluid flows has been examined. In the present work, the stability of Poiseuille flow of a second order incompressible Rivlin-Ericksen fluid in a circular cylinder is investigated by using a linear stability analysis. This method has been used for the classical problems in hydrodinamic stability such as the Rayleigh-Taylor, Kelvin-Helmholtz and Taylor-Couette problems. Here solutions which are independent of the axial coordinate of the cylinder are sought. After obtaining non-dimensionalized form of the field equations correspon-ding to the steady state case, the equations are written in terms of the longitudinal velocity component and a stream function. By using a small parameter, small perturbations to the stream function and to the longitudinal velocity component in the steady case are added. After some manipulations, a single fourth order linear partial differential equation is obtained for the small perturbation term of the stream function. For a linear stability analysis the stream function perturbation is expressed in the form of Fourier modes. In such a case, the linear partial differential equation reduces to a fourth order ordinary differential equation. Then the resulting equation is factorized to two second-order ordinary differential equations which are the Bessel and modified Bessel equations. After applying the boundary conditions the problem reduces to an eigenvalue problem. The eigenvalues which depend on the wave number, the Reynolds number and the second order non-dimensionalized material constant are calculated numerically and the streamlines are depicted for various eigenvalues.

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Topic: 4
Title: *On the Nature of Forces in Fractal Crack Interfaces and*

the Evolution of Fractality
Summary

ON THE NATURE OF FORCES OF FRACTAL CRACK INTERFACES AND THE EVOLUTION OF FRACTALITY

P.D.Panagiotopoulos,
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It is well known that on a fractal boundary the displacements belong to a Besov space and the corresponding forces on its dual space. In the present paper we investigate the nature of these forces and we give some approximation possibilities of the arising force distributions via polynomials. The evolution of fractality is introduced by means of an unknown function (t,d(t)), where d denotes the fractal interface dimension and t the time. We formulate a class of new variational problems, which have the fractal dimension as unknown and we present methods for its determination.

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Topic: 2
Title: 1- *Insability of Flat Surface Under Thermal Stress-Driven Diffusion*
2- *Steady-State Propagation of a Finite/Semi-Infineite Crack in Lattice*
Summary

INSTABILITY OF FLAT SURFACE UNDER THERMAL STRESS-DRIVEN DIFFUSION

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There is a surface and bulk diffusion process localized in the elastic layer loded by a thermal stresses. So the governing equations are the coupled system of diffusion and equilibrium equations of self-consistent diffusion process in the elastic media.

Mass transport by stress-driven diffusion is typically slow, and it can occur to a significant degree only when the process under consideration has the features of relatively high stress, high temperature and small size scale. This features are characteristic of strained-layer semiconductor material systems. Suchsystems provide the phisical basis for the present investigation. The pioneer works of this direction for a suface diffusion belong to Azaro R.J. and Tiller W.A.(1972), Grinfeld M.A.(1986), Srolovitz D.J.(1989), L.B. Freund (1993). The case of bulk diffusion
have been studied by author (1997) who has reduced the correspondent equations to the porous medium equation. Such that some results of Barenblatt G.I.(1984) can be

applied. This two approaches are applied in considering the phenomena of instability of a flat surface in a stressed material under fluctuations in surface shape, and the development of surface roughness.

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STEADY-STATE PROPAGATION OF A FINITE/SEMI-INFINITE CRACK IN THE LATTICE

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Among the problems which may be simulated by the molecular dynamics method there are a class admitting the close form solutions. These are the dynamical problems for a Bravais and non Bravais lattices with linear elastic bonds reducing to a systems of ordinary differential equations with a constant coefficients. The methods of solution of such systems go back to A.A. Maradudin [1] (for a dislocation) and to L.I. Slepian [2] (for a crack) and are based on Fourier-Laplace transforms and factorizaion methods of Wiener- Hopf's type. More complicated case of non-constant coefficients have been examined by means of V.P. Maslov's canonical operator approach [3,4].

Some of the main problems arising during the consideration are:

- the homogenization problem of periodic (quasiperiodic) structures;
- the ergodicity problem;
- the problem of making of canonical factorization and, in particular, the non-uniqueness of the solutions of some steady state problems.

The homogenization of a simple Bravais lattice have been done first by Cauchy [5] The corresponding continuous model is one-constant elastic media. The general form

of a linear interactions in the lattice [4] makes possible to get the classical elastic media as a result of homogenization. It was generalized to non Bravais lattice by V.G. Maz'ya and A.S. Slutzky [6] and then used by M. Marder and S. Gross [7] for 2D simple Bravais lattice. The conditions of ergodicity of a simple Bravais lattice were found by A.M. Frank and N.N. Janenko [8] and extended in [4].

The selection of canonical factorization for some steady state problems was done by L.I. Slepian [2] on the base of L.I. Mandelshtam's principle. It may be done also to taking into account the damping or friction. All possible homogeneous solutions are studied in [9] for a semi-infinite crack moving with a constant velocity. It will be shown the mutual influence of the conditions at the infinity and the number of linear independent homogeneous solutions.

The significant example of a problem which can be analyzed by means of above models is the problem of superdeep penetration [10-12]. The phenomenon has been found for all tested materials of powders and targets. Particles up to 100 microns in size have been situated in the depression of an axisymmetrical cumulative metal envelope and have been accelerated by high explosives to velocities 1-2 km/s. Only a fraction of the particles (less than 1 per cent) penetrate into the target, while other partices remain near the surface of the target, forming many microcraters under the melted layer of powder material due to kinetic energy transformed into plastic deformations, heat and elastic waves.

Investigations of longitudinal and transverse sections of treated samples reveal the presence of many channels inside the sample. The direction of the majority of the channels is the same as that of the powder flux. The diameter of the hollow part of the channel does not exceed several per cent of the particle size but in some regions along the channel there is no powder material detection. Very often the channels are collapsed completely without a hole in the center. The particle's remnant has a stetched shape, in the direction of penetration, and its size is usually about one order less than the initial one. There is often a nearly conical hole spreading in front of the remnant. Sometimes the remnant is situated in a filament-like crack. The depth of penetration can exceed 5 cm and depends on the parameters of the process. This depth is usually less for targets of softer and more plastic materials if the same conditions for the production of powder flux exist.

Above-mentioned facts have been put in the foundation of very simple model [13] of the finite filament-like crack (void) moving with a constant velocity on a background of high-frequency oscillations (elastic waves) which are created by the particles impacted and remaining in the target surface. The used model is the dynamical analog of R. Thomson's model [14].

This problem has been reduced to the spectral problem for some compact operator [15]. It will be shown the corresponding solutions and so it will be found the resonance frequencies of oscillations responding to superdeep penetration.

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Summary:

EFFICIENT DIELECTRIC CONSTANT CALCULATION FOR PERIODIC COMPOSITES

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Calculating the effective dielectric properties of heterogeneous materials is a classical problem in physics and mathematics that dates back to the early works by Rayleigh and Clausius-Mossotti. Its importance stems from one of the basic aims of materials research: relating (predicting) the macroscopic optical and transport properties of inhomogeneous systems to (from) those of atomic or mesoscopic constituents. In the past two decades, there has been a strong revival of interest in composite problems. Various effective medium theories have been formulated to calculate the effective dielectric constant $\bar{\varepsilon}$ of composites with different types of microstructures, e.g., the Maxwell-Garnett theory (for the dispersion microstructure), the Bruggeman's self-consistent theory (for the symmetric microstructure), the theory for the granular microstructures, or the differential effective theory, originally due to Bruggeman (for the hierarchical microstructure). However, all effective medium theories fail in terms of accurately relating an arbitrary microstructure to its complex effective dielectric constant.In view of the recent developments in microtomography, which can routinely generate 3D microstructural data with microns resolution, the lack of a viable theoretical approach to this problem represents a serious gap in our ability to translate microstructural data into meaningful dielectric information.

In this communication, I present an accurate and efficient algorithm for calculating the complex effective dielectric constant of periodic two-component composites with arbitrary unit cell microstructures. Our approach is based on a novel re-formulation of the relevant equations in the Bergman-Milton representation of $\bar{\varepsilon}$, that enables the use of the Fast Fourier Transform (FFT) in their solution process. A direct consequence is that 10^6 - 10^7 Fourier components can be easily handled (on a workstation) in the calculation of the geometric spectral function $\mu(\chi)$. When this FFT approach is coupled with exact known properties of $\mu(\chi)$, accurate evaluation of $\bar{\varepsilon}$ becomes possible as illustrated below, even when the dielectric contrast between the two components, $|\varepsilon_1/\varepsilon_2|$, approaches ∞ and touching microgeometries are present. In particular, we show that our approach accurately reproduces the $\mu(\chi)$ for the 2D checkerboard problem. The ability to treat arbitrary microstructures within the unit cell also means that, as long as the geometric correlation length in a *random* composite is finite and not too large, our approach can yield reasonably accurate results in such cases by using unit cells larger than a typical correlated volume.

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Topic: 2

Title: *Nonlinear Polycrystals with Microstructure Evolution*
Summary

NONLINEAR POLYCRYSTALS WITH MICROSTRUCTURE EVOLUTION

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A constitutive theory is proposed to estimate the effective behavior of polycrystalline aggregates with viscoplastic single-crystal grains and microstructure evolution. The theory is based on a recent nonlinear homogenization procedure by the author and it makes use of variational estimates of the self-consistent type for the instantaneous response of a "linear thermoelastic comparison polycrystal" to generate corresponding estimates for the viscoplastic polycrystal. These estimates incorporate dependence on two sets of texture variables: the crystallographic texture accounting for the orientation distribution function of the randomly oriented grains and the morphological texture characterizing the average shape and orientation of the also randomly distributed grains. In addition, making use of corresponding estimates for the "average" strain rate and spin in the grains of the polycrystal, and of standard kinematical relations, evolution equations are derived for the various texture variables which are fully consistent with the approximations introduced in the homogenization analysis. The resulting constitutive theory has a standard form involving suitably chosen "internal" variables, together with evolution laws for these variables. It includes constitutive equations for the macroscopic strain rate, as well as for the so-called "plastic spin". However, unlike the standard theories, which are based on the Taylor model, the new theory is based on a more accurate homogenization method, yielding results that incorporate statistical information of order two and that are exact to second order in the plastic grain anisotropy. An application will be given for a planar double-slip model and compared with the classical theories.

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Topic: 5
Title: *Continuum Dynamic Theory of Elastoplastic Media with Microstructure*

Summary:

CONTINUUM DYNAMIC THEORY OF ELASTOPLASTIC MEDIA WITH MICROSTRUCTURE

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1. One of main causses impeding building up a closed theory of elastoplastic bodies (in the sense as the theory of elasticity is closed) is that the plastic distortion tensor , which plays a key role in describing elastoplastic media is not a physical state variable. An increment of plastic distortion tensor, correspondingly, does not represent a total differential of a function. It can, however, be reduced to a total differential by multiplying it by an integrating factor. It should be taken into account that an integrating factor can generally be both a function and an operator. For crystalline media, the form of the integrating factor is known: this is the operator of rotation:

$$d\alpha = (\nabla \times d\beta) = curl(d\beta) \qquad (1)$$

The new quantity α introduced by this operation is known as the dislocation density tensor and is a function of physical state (1). Indeed, the dislocations can directly be seen, for example, in high resolution electron microscopes. In this manner configurations and densities of dislocations can be measured without knowing anything about the previous history of the crystals.

2. Being a function of physical state of a crystalline medium, the tensor of dislocation density does not represent, however, a good dynamic variable of elastoplastic medium, as it does not define uniquely its energy. Indeed, by the same macroscopic dislocation density, the dislocations can form either high or low energy configurations (an example of the latter are the small angle misorientation boundaries). To unambiguously define the energy of a crystal Kroener proposed (2) to use, apart from the macroscopic tensor of dislocations which is the first moment (or "one-point" correlation function) of dislocation, also the higher, n-point dislocation correlation tensor functions.

Under certain conditions, however, the first order correlation function (macroscopic dislocation density tensor) proves to be sufficient for describing the dynamics of elastoplastic medium. We show in this paper that this is possible either in the case when the medium is characterised by a certain meso-substructure determining the overall character of the dislocation distribution in the material, or in the case of homogeneously distributed dislocations.

3. It has been shown in (3) that if the edge dislocations are placed in glide planes separated by a distance d and the distance between the neighbouring dislocations within the glide planes is a, then the only non-zero component of the (macro) moment stress in the medium is

$$\bar{\tau}_{xz} = \frac{\pi^2}{24}\frac{Gb}{1-\nu}\frac{d}{a} \qquad (2)$$

Here G is the shear modulus, ν is Poisson 's number, and b is the length of the Burgers vector; x-axis defines the direction of the Burgers vector and z-axis the direction of dislocation lines. All quantities marked by a bar are macroscopic fields.

Obviously the moment stress (2) can not generally be an represented as an unambiguous function of dislocation density tensor

$$\bar{\alpha}_{zx} = \frac{b}{ad} \tag{3}$$

However, if there are some reasons to assume, that some definite dislocation distribution is realised, then the energy can prove to be well defined function of the macroscopic dislocation density tensor. Let us consider two cases.

Medium with meso-subsructure.

Consider a medium with some meso-substructure which causes preferable deformation along some glide planes separated by a distance d, the latter being constant in the course of plastic deformation, In this case, the moment stress can be represented as

$$\bar{\tau}_{xz} = a_{xzxz}\bar{\alpha}_{zx}, \qquad a_{xzxz} = \frac{\pi^2}{24}\frac{G}{1-\nu}d^2 \tag{4}$$

Correspondingly, the energy density of elastic stresses created by such dislocation distribution is

$$U = \int \bar{\tau}_{xz} d\bar{\alpha}_{zx} = a_{xzxz}\frac{\bar{\alpha}_{zx}^2}{2} \tag{5}$$

In the situation described, the distance d and thus the material constant a_{xzxz} do not change in the course of plastic deformation. The energy of the dislocation ensemble is therefore unambiguously defined by its macroscopic density. This means that the tensor of dislocation density is a good dynamic variable for the "medium with meso-substructure" in the described sense.

Medium without meso-substructure

In the contrary case of a "structureless" medium one can anticipate that a chaotic, nearly homogeneous, dislocation distributions will arise. We can hope to obtain a good qualitative estimation for the energy of a chaotic distribution of dislocations, if we set in (2) a $\approx$ d:

$$\bar{\tau}_{xz} = \frac{\pi^2}{24}\frac{Gb}{1-\nu} \tag{6}$$

In this case, the moment stress do not depend on the dislocation density at all, and the energy density will be a linear function of the dislocation density:

$$U = \int \bar{\tau}_{xz} d\bar{\alpha}_{zx} = \frac{\pi^2}{24}\frac{Gb}{1-\nu}\bar{\alpha}_{zx} \tag{7}$$

We again have to do with a case where the energy of the dislocation ensemble is an unambiguous function of macroscopic dislocation density.

4. We mentioned already that the quadratic form (5) for the potential energy implies definite character of "structural organisation" of the medium on the mesoscale, namely, localisation of the deformation in the glide planes separated by a given distance. As an example of such a medium we can consider a crystalline matrix reinforced with hard particles. It is obvious, however, that this structure does not make the dislocations to be concentrated only in the glide planes. They also can build the vertical dislocation walls (for example by the climb motion of dislocations). If such rebuilding structure is possible, the tensor of macroscopic dislocation density, again, looses its status of a "good" dynamic variable. Such changes of dislocation distribution which decrease the energy of the medium can be described, as shown in [4], by introduction of tensors of plastic and elastic torsion and tensor of disclination density.

Conclusion

The macroscopic mechanics of elastoplastic media should be extended to include new dynamic variables. In some special cases the macroscopic tensor of dislocation density can be chosen as an additional dynamic variable, In other cases, it necessary to introduce the tensor of disclination density as a new independent variable. In the general case the question about the state parameters and suitable dynamic variables of elastoplastic media remains still open. Here the study of dislocation correlation functions might bring us progress.

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Topic: 2

Title: *The Theory of Deformable Porous Media Applied to the Production of Composites*

Summary

THE THEORY OF DEFORMABLE POROUS MEDIA APPLIED TO COMPOSITE MATERIALS MANUFACTURING

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We deduce a three-dimensional model based on the theory of deformable porous media aimed at simulating some injection moulding processes used to fabricate composite materials. It works under non isothermal conditions, includes resin cure and allows the solid constituent in both the dry and the wet region to deform during infiltration. The model is simplified in the one-dimensional case by performing analyticallythe integrations of the mechanical equations in the uninfiltrated region. The remaining system of partial differential equations in the two interfaced and time-dependent domains is then posed with the proper interface and boundary conditions both in the case of given inflow velocity and in the case of given pressure cycle. After writing for numereasons the problem in a A Lagrangian formulation fixed on the solid constituent is then introduced to study the problem from both a qualitative and a quantitative viewpoint.Domain decomposition techniques are then used for the simulation.

Keywords: Analytical modelling, Injection moulding, Resin transfer moulding (RTM), Deformable porous media, Composites.

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Topic: 4
Title: *Solitons as Quasiparticles*
Summary

SOLITONS AS QUASIPARTICLES

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Quantum behaviour of soliton formations in deformable solids is considered. A new approach to solitons is proposed based on a general nonlinear theory of quasiparticles in deformable lattice structures. It is shown that due to quantum effects such "heavy" formations as crowdions and kinks in polyacetylene turns into gapless quasiparticles with very small effective masses. The new nonlinear quasiparticles are characterized with their quasimomentum and dispersion law. Mass transport in b.c.c. metals like Na and K is explained in terms of crowdion diffusion. Supersound propagation of solitons and Cherenkov-type phonon emission by crowdions is considered.

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Topic: 3

Title: *The renewal and statistical equilibrium of the epidermis: Biomechanics of tissues.*

Summary

THE RENEWAL AND STATISTICAL EQUILIBRIUM OF THE EPIDERMIS: BIOMECHANICS OF TISSUES.

Nicolas Rivier *and* Benoit Dubertret
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A biological tissue is a geometrical, space-filling, random cellular network, a foam; it remains in a steady state while individual cells divide. Cell division is a local, elementary topological transformation which establishes statistical equilibrium of the tissue and ensures its renewal. It is also the creation of a pair of dislocations, which can climb apart through further divisions. Thus, a tissue is an excellent application of continuous mechanics of discrete systems. Stresses are caused by dislocations, and screened by the disorder. There is also gauge (local) invariance, Burgers contour and a topological Gauss theorem.

As an example, the second part of the lecture will deal with the dynamics of the basement membrane of the mammalian epidermis, when basal cells detach or divide. The steady state of the tissue (in excellent agreement with experiment) is characterized by the division and the disappearance of cells in a two-dimensional faom (modellling the basement membrane). The biological behaviour of a basal cell (division or detachment) is predicted to depend chiefly on the numbers of its neighbours. This suggests that the main factor determining the fate of basal cells, and thus controlling the renewal of the epidermis, is mechanical: It is the local stress, determined by the surface tension and adhesion of the cells.

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Topic: 1

Title: *Thermodynamics and Wellposedness of Constitutive Differential Equations In Continuum Mechanics*

Summary

THERMODYNAMICS AND WELLPOSEDNESS OF CONSTITUTIVE DIFFERENTIAL EQUATIONS IN CONTINUUM MECHANICS

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Wellposedness of constitutive differential equations is one of the main conditions for succeseful modelling in continuum mechanics. This is the guarantee of correct using of effective computational methods specifically.

We propose a class of systems of differential equations which wellposedness ensured by the first law of thermodynamics, that include numerous examples of continuum mechanics equations.

The investigation of the connection between thermodynamics and wellposedness of differential equations was started in Godunov's work in 1961 and was continued by Friedrichs, Lax, and many other researchers. In these works various classes of systems of conservation equations were considered. Thermodynamical properties of such systems give possibility to reduce them to symmetric hyperbolic form. This circumstance ensures the wellposedness in a sence. But all mentioned works have the certain defects. One of them is the presence of the several "thermodynamic" potentials in the constitutive equations, whereas the classical thermodynamics use only one potential.

We propose the new class of the systems of conservation equations which we call thermodynamically compatible systems. Every system belonging to this class generated by the one thermodynamic potential only and can be reduced to the symmetric hyperbolic form.

Proposed class includes numerous systems of differential equations of continuum mechanics such as equations for nonlinear elasticity, slowly moving dielectrics, superfluid helium.

Besides, such approach makes it possible to create new wellposed versions of constitutive differential equations for such complex media as nonlinear composite materials, two-phase two-velocity media, flowing of a liquid through elastoplastic sceleton.

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Topic: 5

Title: *Dislocations and Disclnations in Thin Films, Small Particles and Nanocrystals*

Summary

DISLOCATIONS AND DISCLINATIONS IN THIN FILMS, SMALL PARTICLES AND NANOCRYSTALS

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In thin films, small crystalline particles and nanocrystals, the two following features are of great importance: nanoscale size of regions with perfect atomic structure and the presence of interfaces (free surfaces, grain and phase boundaries). The mechanical behaviour of such materials strongly depends on the interaction of structural defects (vacancies, dislocations, disclinations) with the above interfaces. The stability of dislocations in small particles and nanocrystals is considered. It is shown that there is a critical size of particles or grains below which dislocations are unstable in the grain interior. The reasons for such an instability are ``image" forces of an elastic nature, which strongly depend on the nanocrystallite size. The elastic stresses and energies of dislocations and disclinaitons are calculated for various geometries of defect line and the shape of the nanoparticles. The boundary value problems are solved for a dislocation loop in a spherical particle or for straight dislocations and disclinations in a thin plate and cylindrical and spherical particles. The solutions of the problems for disclinations are applied when analyzing the stability of pentagonal small particles and considering the domain structure formation in ferroelastic thin films. The influence of the peculiarities of the defects on mechanical properties of nanophase materials is discussed. For example, the generalization of the Hall-Petch dependence for nanocrystals is proposed; the process of the diminishing of threading dislocation density in thin buffer layers is also explained. The presented approach may be considered as a theoretical basis for understanding the mechanical behavior of nanophase materials.

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Topic: 4 –
Title: *Waves in Piezoelectric Random Media*
Summary

WAVES IN PIEZOELECTRIC RANDOM MEDIA

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A new theory has been developed for the analysis of the overall properties and the propagation of waves though inhomogeneous piezoelectric materials with randomly distributed microstructure. The self-consistent method has been used by means of a very simple instrumentation, which allows the prediction of resonance phenomena for wavelengths comparable to the diameter of the inclusions. This variant has already been shown to be very versatile and it has a good prediction capability since its wave characteristics comparewell with experiments for the uncoupled counterpart problem in elasticity. Here the problem of predicting the overall properties for 0--3 connectivity piezocomposites and wave propagation through a piezoelectric matrix containing piezoelectric ellipsoidal inclusions, randomly positioned, but with a fixed orientation are studied. The single scatterer problem, which is needed as part of the implementation of the method, is posed as coupled integral equations for the polarizations of momentum density, stress and electric displacement using the piezoelectric Green's function for a transversely isotropic media. The integral equations are solved approximately by means of Galerkin's method. A new generalized algebra of the type that Hill used for transversely isotropic elastic symmetry is developed further. This is instrumental in reducing the final number of equations to a minimum. They are implicit equations which can be solved by iteration using a continuation method in the frequency for the overall elastic, piezoelectric and dielectric properties of the piezocomposite. From these an eigenvalue problem yields the phase speed and the attenuation of the waves as a function of the frequency of the waves in a equivalent homogeneous, but attenuative, piezoelectric composite. The results shows a characteristic resonance phenomena which depends onthe azimuthal angle and type of wave.

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Topic: 6

Title: *A Non-Conventional Gauge-Approach towards a Continuum Theory of Dissipative Deformation-Processes*

Summary

A NON-CONVENTIONAL GAUGE-THEORETICAL APPROACH TOWARDS A CONTINUUM THEORY OF DISSIPATIVE DEFORMATION-PROCESSES

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Gauge field theories are frequently used in particle physics. During the last decades some attempts have been made to establish gauge theoretical methods in continuum mechanics, too. However, my approach is quite different from that one of conventional gauge theories: The symmetry requirements for the Lagrangian are derived from structure of the relevant balance equations of the system. They are formally constructed by means of two different mathematical procedures:

At first, Lie-symmetries associated with balance equations of the volume-type by means of Noether's theorem: E.g. time and space translations are associated with the balances for energy and momentum.

The balances for vortex dynamics and for dislocation dynamics of deforming media, however, are examples for area-type balances which are formally different from the volume-type ones. These balances are outside the scope of Noether's theorem.

I have established a procedure analogous to but different from Noether's theorem: Non-Lie regauging symmetries are associated with area type-balances. Taking both different mathe-matical procedures into account essential symmetry requirements on the analytical structure of the yet unknown Lagrangian become apparent. They allow for the construction of Lagrangians for the deformation dynamics of various materials.

The methods will be demonstrated by means of two examples: The vortex dynamics of a viscous fluid and the dislocation dynamics of elastically and plastically deforming crystals are physically different. Nevertheless there are remarkable formal similarities with respect to my methodical approach.

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Topic: 2
Title: *Transport and Diffusion in Porous Media*
Summary

TRANSPORT AND DIFFUSION IN POROUS MEDIA

Larry Schwartz
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Problems involving transport in porous media are of interest throughout the fields of petroleum exploration and environmental monitoring and remediation. The systems being studied can vary in size from centimeter scale rock or soil samples to kilometer scale reservoirs and aquifers. Clearly, the smaller the sample the more easily can the medium's structure and composition be characterized, and the better defined is the associated computational problem. The analysis of transport in such geological

systems is then similar to corresponding problems in the study of other heterogeneous systems such as polymer gels, catalytic beds and cementitious materials.

The defining characteristic of porous media is that they are comprised of two percolating interconnected channels, the solid and pore networks. Transport processes of interest in such systems typically involve the flow of electrical current, viscous fluids or fine grained particles. A closely related phenomena, nuclear magnetic resonance (NMR), is controlled by diffusion in the pore network. We will review the development of two and three dimensional model porous media, and will outline the calculation of their physical properties. Of particular interest are systems that are uniform when viewed above a certain cutoff length scale but are heterogeneous below that length scale. This is often the case in systems of geological interest and we will present new results related to the interpretation of NMR and transport measurements on reservoir rocks with combined inter-granular and micro-porosity.

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Topic: 3
Title: *Continuum Kinematics, Force and Stress Theory forGrowth and Remodeling*

Summary

CONTINUUM KINEMATICS, FORCE AND STRESS THEORY FOR GROWTH AND REMODELING

Reuven Segev
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Summary: Traditional continuum mechanics regards material points and subbodies as absolute quantities so that they are conserved in all configurations of a body. This basic assumption, known as the "axiom of material impenetrability" allows the straightforward definition of such a basic notion as the velocity field.

A continuum theory of growth should allow addition and removal of material points while generalizing the traditional approach and notions. In addition, growth can develop in various modes such as "volumetric growth", "surface growth", phase transition, etc. It is desired that a continuum theory of growth be general enough to encompass these modes.

We propose a global theory of growth in which a configuration space for the growing body is constructed. This infinite dimensional manifold combines the kinematics of deformation with the kinematics of growth. A tangent vector to the configuration

space will represent both the velocity of the material points and the growth rate. The decomposition of a tangent vector into two such components that are invariant is discussed.

Forces are described as elements of the cotangent bundle of the configuration space. This implies that forces associated with growth are presented naturally. These forces, generalizing the traditional "configurational forces", are shown to be associated with stresses, the counterparts of the Eshelby stresses.

Additional features of growth theory such as material flow and remodeling will be presented from a similar point of view.

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Topic: 1 (oral) , 5 (poster)

Title: 1- *The Mechanical Foundation of the Fokker-Planck equation and its Generalizations* (with E.Fried-Oral Presentation)

2- *Continuous Distributions on Dislocations* (with C. Cermelli-Poster Presentation)

Summary

1-(Oral Pre.)

THE MECHANICAL FOUNDATIONS OF THE FOKKER-PLANCK EQUATION AND ITS GENERALIZATIONS

S. Sellers *and* E. Fried.
University of East Anglia, Norwich, UK

A general mechanical framework is given for the Fokker-Planck equation based upon a microforce balance and a probability balance. Nonlinear constitutive theory is developed and a mechanical version of the second law provides constitutive restrictions. Illustrations of special cases such as rotational diffusion as well as various generalizations of the classical theory are given.

2-(Poster Pre.)

THE MECHANICS OF DEFECTIVE CRYSTALS

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P. Cermelli
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Basic ideas in the mechanics of crystals with continuous distributions of point and line defects are revisited from a new perspective, emphasizing the role of

configurational forces. Additionally the creation, destruction, and transport of defects is presented in detail. The formulation of the balance laws is given over time-dependent spatial control volumes; furthermore independent configurational and deformational force balances are postulated. Such a formulation is more versatile than one with standard fixed control volumes, and provides the correct Eshelby relation from simple invariance arguments independent of constitutive relations. Two alternative but equivalent constitutive models are proposed and the corresponding restrictions following from a dissipation inequality are determined. Relations to some previous formulations of continuous distributions of dislocations and vacancies are discussed.

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Topic: 2-3
Title: *Micromechanical Design of Materials for Bone Implants*

Summary

MICROMECHANICAL DESIGN OF MATERIALS FOR BONE IMPLANTS

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Recent developments in the design of bone replacement materials has been towards the use of materials, which allow bone to grow and attach onto their surface. Hydroxiapatite (HA) has been extensively investigated, but it is limited to low-load applications. There is a greet need for producing materials with both different biocompatibility and higher mechanical properties than sintered HA, as mechanical compatibility with the surrounding host tissue is also an absolute requisite for a sound implant-tissue interface. One solution to this problem is to use HA reinforcement with some plastificator inclusions. It is well known approach in design of the shockproofpolystyrol and ABS-plastic. In the case of biomaterials this method have come in considerable current use. In this research we also consider a possibility of HA reinforcement with artificial or natural polymer inclusions. That allows to obtain elastic-viscoplastic material without loss of biocompatibility if the inclusions are

bioinert or the collagen is used as a reinforcement material. We discuss here an applicability of methods of nonlinear mechanics of composites for the design of artificial biomaterials. The goal of the research, as a whole, is to obtain diagrams of recommended mechanical properties of possible plastificator depending on the volume concentrations of the phases. In this study we only consider elastic moduli and yield stress of the plastificator. The material is modelled by bolls with complex rheology which are distributed in elastic matrix HA. solution is based on the generalisation of Eshelby' theorem about ellipsoidal inclusion in the elastic medium. According to this theorem stress field in the single ellipsoidal inclusion sealed into linear elastic matrix will be uniform, if the system is loaded by uniform external forces. It does not depends on the rheology of the inclusion material. This result allows to use self-consistent scheme of averaging. We have used the effective field scheme, according to which every inclusion is considered as isolated one fixed into the homogeneous medium with the properties of matrix and the presence of surrounding inclusions is taken into account by the introducing of additional effective strain field. In order to reduce the relation obtained to linear integral equations we use the thermodynamic time scale, proposed by Vakulenko. It permits to use Boltsman superposition principle for physically nonlinear processes. The proposed approach allows to obtain analytical relations for the reinforcement material in order to get the mechanical properties of the designed composite similar to those in the cortical bone as close as possible. The formulae for the bulk and shear moduli and yield stress of the plastificator are reasonably easy and can be used directly in the design of biomaterials.

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Topic: 7

Title: *Diffraction of Antiplane Surface Wavesby an Edge Crack in a Layered Piezoelectric Half Space*

Summary

DIFFRACTION OF ANTIPLANE SURFACE WAVES BY AN EDGE CRACK IN A LAYERED PIEZOELECTRIC HALF SPACE

Y. Shindo and F. Narita
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Numerous investigators have recently demonstrated the feasibility of active structural control using active materials. The use of lead zirconate titanate (PZT) ceramics as actuators and sensors for beam and plate vibration has been studied. The strength of the piezoelectric materials is weakened by the presence of defects such as voids and cracks. The analyses of cracked piezoelectric materials have thus been performed by several researchers, due to the brittle nature of piezoelectric materials.

Many piezoelectric devices are constructed of both piezoelectric and structural layers, and understanding of fracture process of piezoelectric structural systems is of great importance in order to secure the structural integrity of piezoelectric devices. In this paper, based on the dynamic theory of linear piezoelectricity, we investigate the diffraction of antiplane surface waves that are incident on an edge crack in a layered piezoelectric half space. The piezoelectric layer is perfectly bonded to a half space of a different elastic solid and the crack is normal to the free surface. Both cases of a partially broken layer and a completely broken layer are studied. The technique consists of the reduction of the related dual integral equations of the problem to a singular integral equation. A number of examples are given for some layered piezoelectric materials. The results show that the effect of the electroelastic interactions on the dynamic stress intensity factor and the dynamic energy release rate can be highly significant. We also assess the effect of the electrical boundary conditions on the propagation of antiplane surface waves in a layered piezoelectric half space and show that the impermeable assumption is valid for an interface between the piezoelectric layer and the half space.

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Topic: 2
Title: *Recent Advances in the Modeling of Failure Phenomena of Piezoelectric Ceramics*
Summary

RECENT ADVANCES IN THE MODELING OF FAILURE PHENOMENA OF PIEZOELECTRIC CERAMICS

Horacio Sosa
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Piezoelectric ceramics are being the subject of intense research studies due to their use in advanced technological areas. An issue of extreme concern is their reliability in environments where complex physical phenomena takes place. Typical examples are electromechanical devices, electronic components, micromechanical systems and sensors and actuators embedded in intelligent structures. In these and other applications loadingconditions of mechanical, thermal and electrical nature tend to produce large stresses and electric fields, which may cause deleterious processes like depoling, dielectric breakdown and even catastrophic failure.

This communication summarizes our recent studies, which have been performed within the framework of both static and dynamic continuum electrostatics. Emphasis will be placed on showing the theoretical developments of a boundary element methodology to address problems of practical significance involving piezoceramics

like (a) the behavior of electro-elastic fields around embedded electrodes; and (b) transient dynamic effects induced by electric impulses.

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Topic:
Title: *A Model for Granular Material Mechanics Combining the Double-Shearing and Critical State Concepts*
Summary

A MODEL FOR GRANULAR MATERIAL MECHANICS COMBINING THE DOUBLE-SHEARING AND CRITICAL STATE CONCEPTS

AJM SPENCER
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Numerous proposals been made for setting up systems of equations to model the mechanical behaviour of granular materials. Many of these have some desirable features; all of them appear to have some undesirable features; and none of them has achieved general acceptance. It is quite widely agreed that the Coulomb-Mohr criterion, or a modification, or a modification thereof, together with the equations of equilibrium, gives an adequate description of the stress in quasi-static deformation of a body of granular material. The difficulty lies in the formulation of equations to relate thedeformation or flow to the stress. In this paper we consider two competing theories and attempt to reconcile their most attractive features.

The critical state theory postulates the existence of a critical state, in which the pressure, maximum shear stress and specific volume satisfy a pair of relations, and proposes that the material will consolidate or dilate during deformation in such a way as to approach a critical state asymptotically, In addition the theory assumes that the strain increments are derived from a plastic potential which, for an isotropic material, is an isotropic function of the stress. A consequence of this latter assumption is that the principal axes of the stress and strain--rate tensors are coincident. There is strong evidence that this coaxiality of stress and strain---rate does not necessarily occur in real granular materials. The douple-shearing model proceeds on a different basis, essentially by postulating that deformation occurs by shear on the two surfaces on which the critical shear stress defined by the Coulomb-Mohr criterin is mobilised. In general the principal axes of stress and strain-rate do not coincide, but the theory, in its original form, does not include dilation and consolidation.

In our view the main drawback of the critical state theory is the adoption of a plastic potential for which the justification is rather weak in the context of frictional materials. We show that if this assumption is abandoned, the remaining features of the ccritical state and double-shearing models can be combined to produce a self-consistent theory that does not require coaxiality but which retains the concept of the

critical state. The theory is illustrated by its application to an analysis of the triaxial test.

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Topic: 5
Title: *Consideration of Processes on the Microscale and Mesoscale for the Development of Constitutive Models for Metallic Materials*
Summary

CONSIDERATION OF PROCESSES ON THE MICROSCALE AND MESOSCALE FOR THE DEVELOPMENT OF CONSTITUTIVE MODELS FOR METALLIC MATERIALS

Elmar STECK
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Processes on the microscale determine the macroscopic behaviour of metallic materials and should therefore be considered during the development of constitutive macroscopic equations used for engineering calculations. The paper reviews the mathematical formulation of the most significant of these processes, such as dislocation motion due to thermal and mechanical activation and the development of internal structures during plastic deformation. It describes the consideration of these relation in a stochastic model for the inelastic behaviour of metals and shows the comparison between predictions of this model and experimental findings.

Most engineering materials possess a polycrystallin structure, Under load, the anisotropy of the constituent grains causes strong inhomogeneoities of stresses and strains between and inside the grains. Especially strain localisations are of great importance because they are possible starting points for damage. In order to investigate these local deformation processes, a model based on the Finite-Element Method is introduced. The main purpose of the model is to investigate the local deformation behaviour of polycrstals on the grain level, Numerical simulations of local plastic flow in polycrystals are in good agreement with the results of metal physics and experiments.

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Topic: 7-GL
Title: *Micro-Macro Trnsitions in Nonlinear Mechanics*
Summary

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Topic: 1

Title: *A New Classical Effect: Magneto-Induced Anisotropy of Magneto-Transport Properties in Composite Medium with a Periodic Microstructure*

Summary

A NEW CLASSICAL EFFECT: MAGNETO-INDUCED ANISOTROPY OF MAGNETO-TRANSPORT PROPERTIES INCOMPOSITE MEDIUM WITH A PERIODIC MICROSTRUCTURE

Yakov M. Strelniker and David J. Bergman
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It is often assumed that any interesting new phenomena in solid materials must have their origins in quantum behavior. We are reporting here about an entirely classical unexpected new phenomenon recently predicted [1] and already experimentally verified [2]. For a strong magnetic field, the values of magnetoresistance tensor components (as well as the electrical permittivity in case of low-frequency fields) exhibit a strong dependence on the direction of the applied magnetic field **B**. The angular profile of magnetoresistance is qualitatively similar to what isexperimentally observed in some metallic single crystals like Gold and Copper and is usually explained by invoking a Fermi-surface quantum theory. However, the discussed phenomenon is well described by a classical continuum physics picture, wherein the local electric current density at any point $\mathbf{J}(\mathbf{r})$ depends on the electric field at the same point $\mathbf{E}(\mathbf{r})$, by means of a local conductivity tensor $\hat{\sigma}(\mathbf{r})$ which characterizes the transport properties of the solid material at that point $\mathbf{J}(\mathbf{r}) = \hat{\sigma}(\mathbf{r})\cdot\mathbf{E}(\mathbf{r})$. The new behavior that was found is due to the step-function heterogeneity of $\hat{\sigma}(\mathbf{r})$, and to its nonlinear dependence on **B**. It is a result of the complex interaction between the cigar-shaped regions of the current distortion, $\delta\mathbf{J}$, produced by different inclusions placed in a periodic array. The above results are found due to the new numerical and analytical methods developed by us to treat periodic composite media. Those methods allow us to calculate both the local current and field distribution, as well as the bulk effective conductivity tensor, in such composites with arbitrary conductivity and shape of the inclusions, in the presence of an arbitrarily strong magnetic field.

The classical strong field magneto-transport properties of periodic composites are proving to be a source of remarkable new phenomena. There is a clear need for more experimental and theoretical studies of such systems.

[1] D. J. Bergman and Y. M. Strelniker, Phys. Rev. B **49**, 16256 (1994).

[2] M. Tornow, D. Weiss, K. v. Klitzing, K. Eberl, D. J. Bergman, and Y. M. Strelniker, Phys. Rev. Lett. 77,147 (1996).

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Topic: GL

Title: *Equilavance Transformations for Second Order Balance Equations*

Summary

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Topic: 2

Title: *Third-Order Bounds for the Overall Properties of a Nonlinear Dielectric Polycrystal*

Summary

THIRD-ORDER BOUNDS FOR THE OVERALL PROPERTIES OF A NONLINEAR DIELECTRIC POLYCRYSTAL

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The Hashin-Shtrikman methodology for nonlinear composite problems relies on the use of a comparison medium. An approach originated by P. Ponte Castaneda employs a comparison medium which is itself a linear composite with the same microgeometry as the nonlinear composite. When the method is applicable, the resulting bounds for the nonlinear problem involve bounds for the energy of the comparison composite which could include three-point information about the microstructure. However, at most one bound (either upper or lower) can be obtained using a linear comparison material. In order to obtain the other bound, a nonlinear comparison material is used. A recent approach which uses a nonlinear comparison composite will be described in

the context of a nonlinear dielectric polycrystal. The resulting bounds involve a parameter introduced by M. Miller which incorporates three-point information about the microstructure. Results are presented for a composite consisting of a linear polycrystal in which one nonlinear phase is embedded.

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Topic:
Title: *Microstructural Effects on the Fracture of Concrete*
Summary

MICROSTRUCTURAL EFFECTS ON THE FRACTURE OF CONCRETE

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B.I.G. Barr *and* F.D. Lydon
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The interface between the aggregate and cement paste is the weakest link, as a result of this, the mechanical behavior of concrete is significantly affected by the properties of the interfacial zone, being especially sensitive to the properties of this zone. The development of bond cracks at the matrix-aggregate interfaces plays an important role in the fracture of concrete. The type of aggregate and the stiffness between the aggregate particles and the matrix strongly affect the mechanical properties of concrete.

The influences of silica fume, type and size of aggregate on the pre-and post-peak response of high strength concretes in bending were investigated by measuring the facture energy G_F, the characteristic length l_{ch}, and brittleness index B. Degradation of stiffness and strength were also measured and a unique focal point was determined using unloading-reloading cycles during the tests. The degradation of stiffness was correlated to the local fracture energy, strength degradation, permanent CMOD (Crack Mouth Opening Displacement), and permanent displacement at mid-span (δ). It was shown that relations between normalized stiffness, load, local energy, CMOD and δ were independent of the partial replacement of cement by silica fume and of the type and size of aggregate. Based on the fracture tests and microscopic studies at the matrix-aggregate interface. It was concluded that, in both limestone and gravel concretes without silica fume, the cement-aggregate interface had a large amount of calcium hydroxide and also much less dense calcium silicate hydrate; however, in

concretes with silica fume, the interfacial zone became stronger, more homogeneous an dense. In the latter concretes, the fracture energy decreased dramatically, especially when they contained 20 mm maximum size aggregate, and in these concretes, the brittleness index was substantially high. In gravel aggregate concretes with and without silica fume, cracks developed around the aggregates and generally did not traverse them, due to the particle shape and smooth surface; however, in concretes with silica fume, crack surfaces were less tortuous and fracture was in a more brittle manner. In limestone concretes with silica fume the cracks usual traversed the aggregates; a transgranular type of fracture was observed.

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Topic: 4

Title: *Propagation of Nonlinear Surface SH Waves in a Layered Hyperelastic Half-Space*

Summary

PROPAGATION OF NONLINEAR SURFACE SH WAVES IN A LAYERED HYPERELASTIC HALF-SPACE

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We have considered the propagation shear horizontal (SH) surface waves in an elastic half- space covered by two different elastic layers each of uniform thickness. It is assumed that the constituent materials are homogeneous, isotropic and hyperelastic and stresses and displacements are continuous at the interfaces and the free surface is free of tractions. Then the problem is investigated by employing the method of multiple scales supposing that the amplitude of waves is finite but small, and between the linear shear velocities of the layers (c_1, c_2) and the half space (c_3) the inequalities $c_1<c_2<c_3$ are valid. It is well known that for the existence of a surface SH wave, the phase velocity c of the wave must satisfy either $c_1<c_2\leq c<c_3$ or $c_1<c\leq c_2<c_3$. It is shown that, in both cases, the nonlinear modulation of surface SH waves is governed by a Schrodinger (NLS) equation. As the properties of solutions of the NLS equation depend strongly on the sign of the product of its coefficients, the variation of this product with the wave number is evaluated for the lowest branch of the dispersion relation giving appropriate values to the material constants. It is remarked that solitons may exist depending on theconstitution of the layered half space.

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Topic: 2
Title: *Self Heating of Some Viscoelastic Fluids*
Summary

SELF HEATING OF SOME VISCOELASTIC FLUIDS

Victor TIGOIU.
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The paper discusses some aspects related to the self heating of some complex fluids in flows with preponderant shear character.

In the papers Strivastava [1964], Szesi and & [1985], Rajagopal and & [1990], Gupta and & [1993], Tigoiu [1991], [1995], [1998] some particular flows for complex fluids (generaly represented by constitutive relations of polynomial type) as well as the heat transfer problem are analysed. For instance in Gupta and & [1993], after the analysis of governing equations, Figure 5. suggests that a self heating of the fluid can appear in a preponderant shear flow.

In Tigoiu [1991] and [1995] after the analysis of existence, uniqueness and dependence on the Peclet number (a = RePr) the first two approximations are represented. In the Figures 2-4 ([1991]) and Figures 4-6 ([1995]) a self heating appears, which is more significant in the interior of the flow domain. We can clearly see that (in spite of the fact that these fliuds are slightly viscoelastic) the self heating is more significant as the degree of complexity of the fluid is growing.

In Tigoiu [1998], which is devoted stictly to the subject, the self heating is clearly emphasized for a BKZ fluid. The solution of the flow problem obtained by Rajagopal and & [1983] is employed and it is proved that the heat propagation equation in the orthogonal rheometer is given by $\frac{d^2\theta}{dz^2} = h(z)$. The stress power is computed and an explicit solution is derived (for the corresponding boundary value problem). The temperature variations between the two plates are put into evidence. A grows of about 12% is obtained when the two plates are mentained at the same temperature.

This heating is more important when the distance between the two plates is growing and we conclude that this is the effect of "internal frictions". So the self heating is strictly connected with the microscopic structure of the fluid (which is supported by the close relation between the BKZ model and the structural model of Doi- Eduards). These results will be used to better understand the interdependance between the temperature and the structure of the fluid.

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Topic: 6
Title: *Modeling Neural Networks*
Summary

MODELING NEURAL NETWORKS

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A neural model for image recognition (Dynamic Link Network) is presented and the mathematical problems connected with it are discussed. Practical applications are shown for face recognition as well for analysis of images taken from satellites.

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Topic:
Title: *Microstructural Models for the Spin*
Summary

MICROSTRUCTURAL MODELS FOR THE SPIN.

Carmine TRIMARCO
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The notion of spin is currently associated with that of angular momentum. However, some inconsistencies may arise from this believe. In fact, at the scale of the crystalline lattice cell, the spin variables elude laws and methods of classical mechanincs. The three spin variables are not adequately represented by an ordinary vector, though they transform as vector components. In addition, no Lagrangian form can be associated with the spin. In this respect, the question arises whether the time evolution equation for the spin could be derived from a variational principle. Here, a general set of dynamical variables are examined. One of the result is that these variables may admit a Lagrangian formulation provided that they are even in number. Then, anticommuting variables are introduced and a Poisson dynamics is proposed for them. Such 'extended' dynamical systems are shown to admit a Lagrangian formulation

independently of the number of the variables. In addition, the spin seems to be satisfactorily represented by a set of the novel anticommuting variables.

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Topic: 4
Title: *Bayen-Flato Mechanics and Symmetries of Dynamical Systems*
Summary

BAYEN-FLATO MECHANICS AND SYMMETRIES OF DYNAMICAL SYSTEMS

Gazanfer UNAL
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It has been shown that the dynamical systems possessing $n-1$ independent first integrals admit an intrinsic symmetry vector field which involves Bayen-Flato mechanics. Moreover, in addition to first integrals if the dynamical system admits a *n*-1 parameter Lie group then a new symmetry vector field can be found in terms of these.

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Topic: 2
Title: *Continuum Mechanics in Predicting Behaviour of Discrete Systems*
Summary:

CONTINUUM MECHANICS IN PREDICTING BEHAVIOR OF DISCRETE SYSTEMS

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In view of the success of continuum mechanics in predicting the behavior of gas liquid and solid continua, it is natural to explore the applicability of the methods of continuum mechanics for predicting the behavior of diverse discrete systems, from sand formations, to galactic clusters, from economical conglomerates to molecular ensembles. In continuum mechanics, one deals with a few rules in the form of rate relationships (spatial and temporal) that involve a few behavioral attributes at each of the infinitely dense and uniformly distributed material points of a continuum.

Contrasted to this, in discrete systems, one is confronted with many algebraic relationships involving many behavioral attributes at each of the finite number non-uniformly distributed points of the discrete space. There are other subtle differences between continua and discrete systems on such concepts as curvature, connectedness, and curvature of the spatial space. Considering also the recent successes in handling some of the continuum mechanics problems as discrete ones in digital computers, the paper discusses the conditions for successful applicability of continuum mechanics in discrete systems, and identifies the type of discrete systems that may benefit from continuum mechanics.

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Topic: 6

Title: *The Microscopic Stress Tensor for Systems with Spin-Dependent Many-Body Interactions*

Summary

THE MICROSCOPIC STRESS TENSOR FOR SYSTEMS WITH SPIN-DEPENDENT MANY-BODY INTERACTIONS

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The concept of the microscopic stress tensor field has its roots in the statistical mechanical theory of transport processes. It plays an eminent role in establishing the connection between microphysics and thermomechanics of continua [1,2].

Furthermore, one can show that this tensor field is a key quantity in the realm of all sorts of spontaneous symmetry breakdown, as it is just the appearance of long-ranged correlations involving the stress tensor that signals the existence of density inhomogeneities in the absence of exterior fields [3,4].

The construction of microscopic stress tensors is well established for the case of translation invariant pair interactions [5] and has been extended by the author to position-dependent multiparticle potentials [6].

The present paper is devoted to the generalization of this construction to translation invariant many-body interactions that are also allowed to depend on the momenta and internal degrees of freedom (spin).

In addition, the possibility of symmetrization of such stress tensors is discussed for rotationally invariant interactions of this general type.

Some remarks on quantum mechanical analogies are also given.

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Topic: 2
Title: *On the Interaction between a Crack and Inclusions in Materials*
Summary

ON THE INTERACTION BETWEEN A CRACK AND INCLUSIONS IN MATERIALS

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It is known, that the microstructure of materials affects initiation and propagation of cracks which in turn determines the overall fracture toughness of the material. In this paper, we investigate the influence of soft or hard inclusions on the propagation of cracks in composites. For this, the problem of a homogeneous, isotropic elastic body containing an inclusion or symmetric clusters of inclusions under mode I loading is studied. In order to address practical material problems, the effect of various Young's moduli and locations of the inclusion relative to the crack front are examined in the three-dimensional case. Also, the influence of geometrical factors such as crack length, particle size and crack-inclusion distance is investigated. A comparison is made between a crack penetrating a compact inclusion and a crack penetrating a cluster of inclusions.

In fracture mechanics, criteria for failure are generally based on the analysis of stress and strain states near the crack-tip. To characterise the stress concentration near a crack tip, Rice (1968) proposed the well-known path-independent J-integral. The path-independence however is lost in the case of inhomogeneous materials and an extension of the J-integral concept is needed (see, e.g. Haddi and Weichert, 1995). This concept is used here numerically to characterise crack-inclusion interactions. The 3D J-integral is calculated over a chosen volume by means of a two-points Gaussian integration in each co-ordinates directions. After analysing the crack-inclusion interaction along the crack front, we investigate, what difference it makes if a crack penetrates a compact, square inclusion or a cluster of inclusions of the same total volume.

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Topic: 2
Title: *Continuun Models of Plane Elastic Cellular Media*
Summary

CONTINUUN MODELS OF PLANE ELASTIC CELLULAR MEDIA

Czeslaw WOZNIAK, University of Technology, Czestochowa
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The objective of the contribution is to formulate and apply a new continuum model to study linear elastodynamics for a plane cellular medium of an arbitrary periodic structure.

It is assumed that length dimensions of a representative cell of the periodic structure are small compared to the minimum characteristic length dimension of the whelk medium and that the distribution can be approximated by assigning a concentrated mass and an inertia moment to every nodal point of a cellular medium. Hence, the medium under consideration is represented by a certain plane periodic system or...rigid points. The direct approach to.. ...of periodic systems with a very large number of interacting rigid bodies leads to computational difficulties due to a large number of ordinary differential equations describing the problem under consideration. That is why different averaged continuum models of periodic discrete systems have been proposed in order to simplify the analysis of special problems.

The aim of the contribution is to formulate a refined continuum model of the medium under consideration, ie. a nonasymptotic model which describes the representative periodicity cell size effect of on the global body behaviour. This model can be applied to the analysis of a linear elastic plane cellular media with an arbitrary complex lay-out the representative cell.

The main feature of the model is its relatively simple analytical form given by the partial differential equations of the plane Cosserat continuum coupled with the system of ordinary differential equations involving second order time derivatives of certain extra unknowns called internal variables. The results are applied to the investigation of free vibrations and wave propagation problems.

The physical correctness of the model proposed is shown by comparing the obtained solutions and the exact ones.

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Topic: 2

Title: *The Stability Loss of the Strip Fabricated from the Multilayered Composite Material with Periodically Curved Structere*

Summary

THE STABILITY LOSS OF THE STRIP FABRICATED FROM THE MULTILAYERED COMPOSITE MATERIAL WITH PERIODICALLY CURVED STRUCTURE

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The strip fabricated from the multilayered composite material with periodically curved structure is considered. It is supposed that the normal forces compress this strip with intensity p at the ends, which are simply supported. Employing of continuum approach of Akbarov and Guz' the strip material is modelled as continuous inhomogeneous anisotrop material with normalised mechanical properties. In this case the structural parameters of considered strip material enter these constitutive relations. Moreover, it is supposed that the considered strip has an initial infinitesimal imperfection and in the framework of the geometrically non-linear exact equations the grow of this initial imperfection is studied. The value of p for which the above initial infinitesimal imperfection starts to increase and grows indefinitely, is taken as critical value of p under which the considered strip loses its stability. The investigations are carried out with the use of Finite Element Method (FEM) and the influence of the strip material structure to the critical values of p is studied. In particularly, it is shown that with the increasing of the curving degree in the strip material structure the critical values of p decrease.

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Topic: 5

Title: *Statistical Characterization of Inhomogeneous Dislocation Arrangements*

Summary

STATISTICAL CHARACTERIZATION OF INHOMOGENEOUS DISLOCATION ARRANGEMENTS

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The dislocation arrangements that emerge in the course of plastic deformation (e.g. cell structures) are often strongly heterogeneous. The statistical characteristics of such inhomogeneous dislocation arrangements are discussed. To this end, the probability distribution and spatial correlation function of the local dislocation densities as well as the dimensionality (fractal dimension) of the dislocation arrangement are considered. These quantities are studied for different types of dislocation structures that are observed experimentally. It is shown that the evolution of the statistical characteristics of the dislocation arrangement in the course of plastic deformation may be obtained from simple theoretical models using methods of stochastic dislocation dynamics.

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Topic: 7
Title: *Problems in a Unified Kinematics of Simple and Multilattices*

Summary

PROBLEMS IN A UNIFIED KINEMATICS OF SIMPLE AND MULTILATTICES

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Various crystalline materials useful in the applications undergo solid-state phase transformations with a change of symmetry. For instance the crystal lattice may change from either body-centered or face-centered cubic, to close-packed hexagonal (hcp). In this case the cubic phase can be described by a simple Bravais lattice, but this is not possible for the hexagonal phase. Indeed, the hcp structure is not a simple lattice, for it is formed by a finite number (two, in this case) of compenetrating translates of a given simple lattice. These complex structures, called "multilattices", describe in detail the crystals that occur in nature. We briefly discuss how to treat the symmetry and kinematics of multilattices, and indicate the main problems that stand in the way of a unified description of the symmetry and kinematics of simple- and multilattices.

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Topic: 6
Title: *On Mechanics of Deformable Superconductors*
Summary

ON MECHANICS OF DEFORMABLE SUPERCONDUCTORS

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Superconductors have very unique features not only on the well-known zero-DC resistance, the Meissner effect, and the macroscopic quantum behavior, but also on the response to their mechanical motions. Novel ideas and concepts in continuum physics are therefore required to formulate properly the electromagneto-mechanical behaviors of deformable superconductors. This research communication introduces some recent new results as well as existing problems in the continuum modeling of moving deformable superconductors. It will be shown that the commonly used hypothesis that the macroscopic electromagnetic properties of deformable media in the theory of instantaneous rest-frames are unaffected by accelerations in accordance with Minkowski's theory is not appropriate to model moving deformable superconductors even at the approximation of low speed and low acceleration.
It will be also shown that the presence of various structures of quantized magnetic vortices in high-temperature superconductors in high fields may result in interesting macroscopic electromagnetic and mechanical behaviors of the superconductors, which are still challenges to us in the modeling of these materials, including continuum models. Illustratively, some problems of practical interest in deformable superconductors will be formulated and discussed.

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Topic:
Title: *Statistical Theory of Concentrated Defects in Linear Elastic Media*
Summary

STATISTICAL THEORY OF CONCENTRATED DEFECTS IN LINEAR ELASTIC MEDIA

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The dynamics is based on author's earlier work in which the defect is regarded as a small (pointwise) discontinuity of the displacement on a moving surface. The conventional Liouville equation is used to derive a system of field equations for the mixture of the material elastic body and defect (say dislocation) fluid", the latter being described by the defect density, velocity, etc.

Linearization leads to dispersion laws. One-dimensional nonlinear example is worked out; it leads to a system of 7 partial differential equations, which in the hyperbolic case yield discontinuity surfaces of various kinds, eg. shock waves and slip planes.

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